PROJECTS ■ THEORY ■ APPLICATIONS ■ CIRCUITS ■ TECHNOLOGY

NUTS AND VOLTS

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June 2009

EVERYTHING FOR ELECTRONICS

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This all-purpose circuit will have you shouting "Wunderbar!"

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✦ Ballistic Chronograph

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✦ Electronics Q&A

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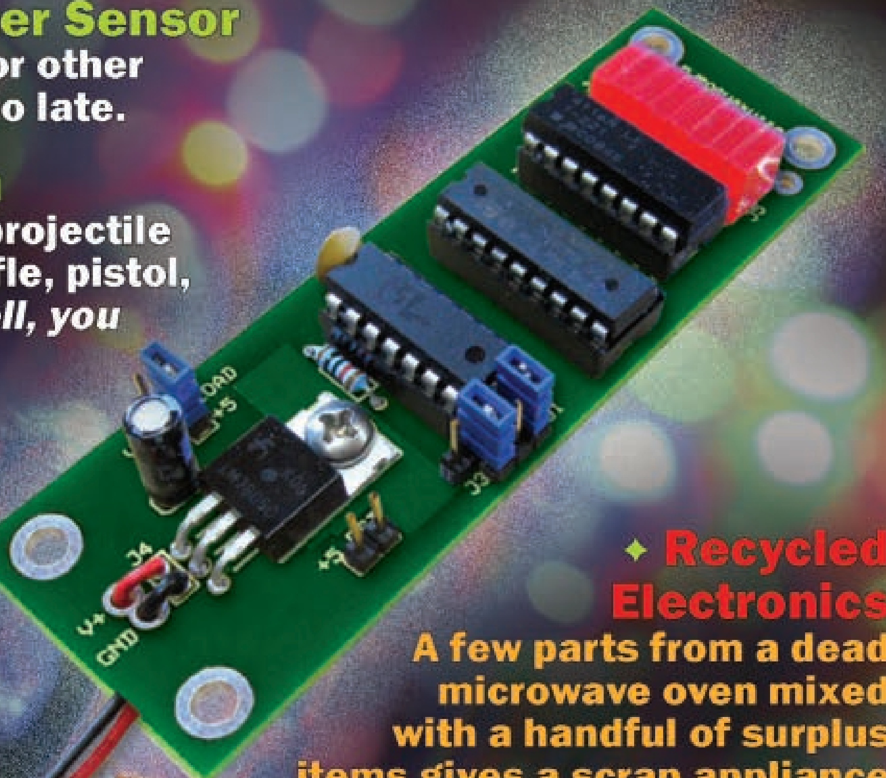
- Antique Tube Radio 90 VDC Power Supply
- Automated Chicken Coop



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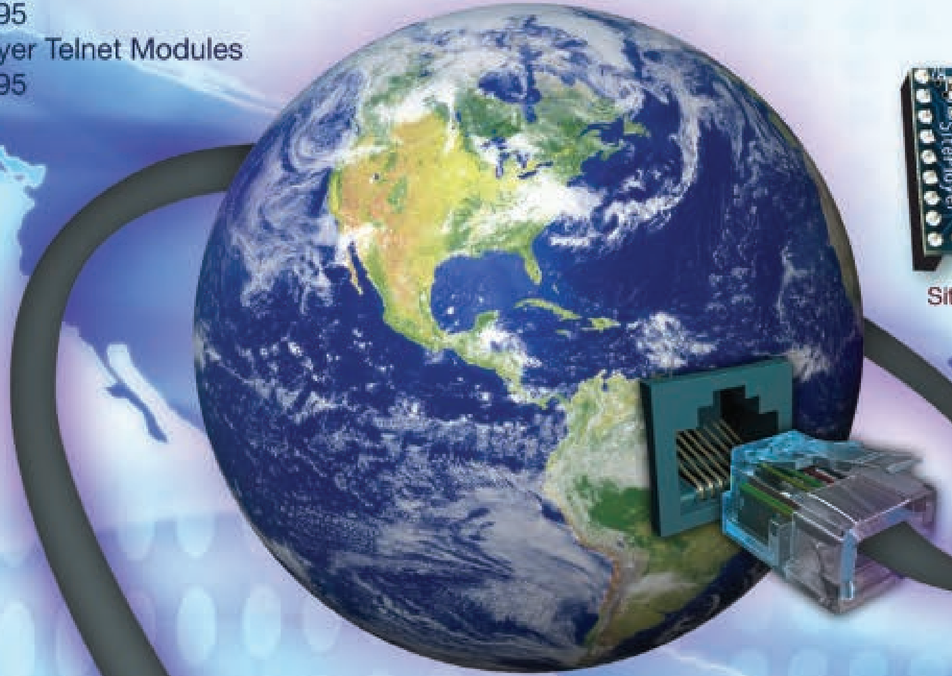

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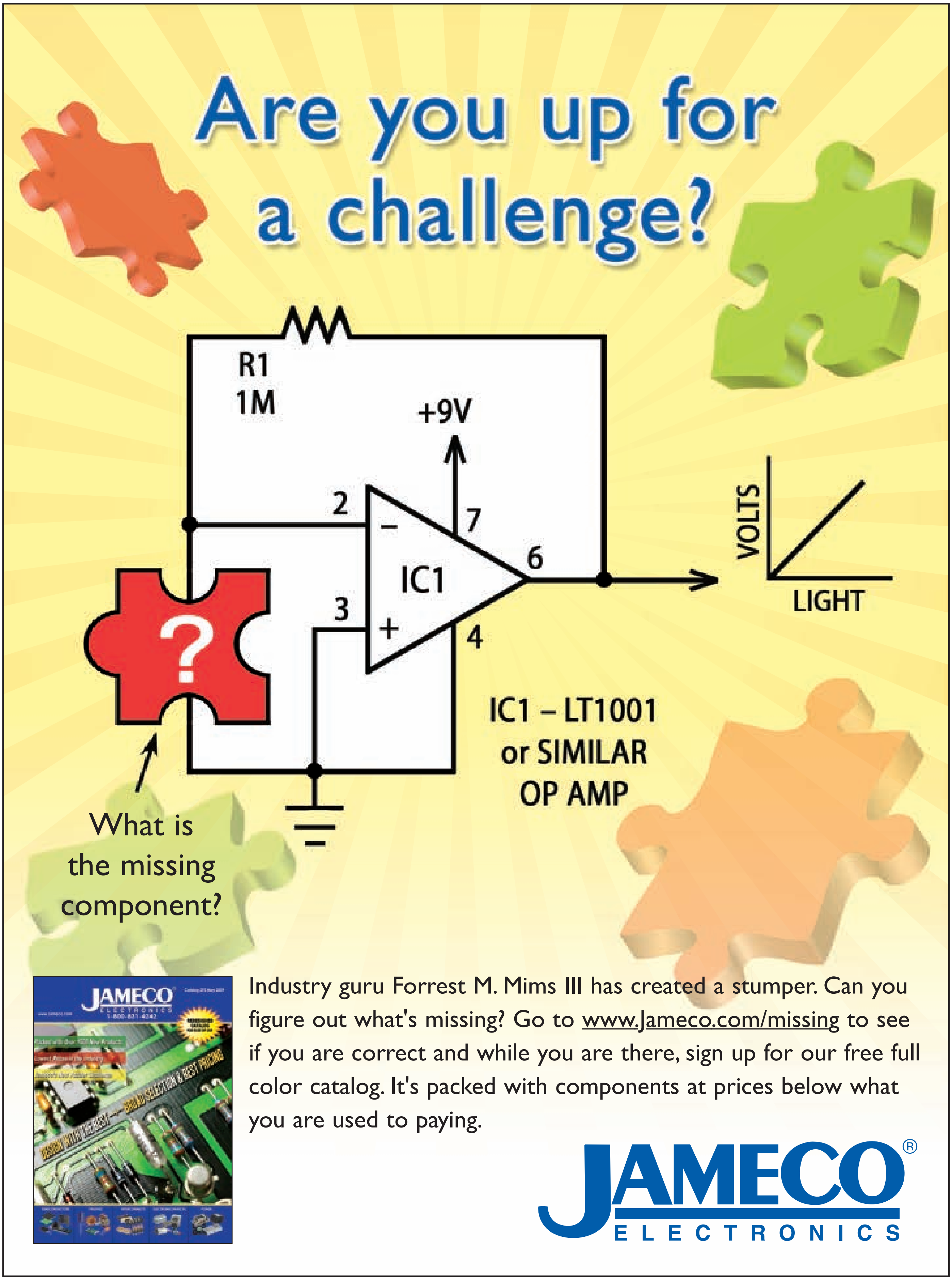
Be safe out there, Michael!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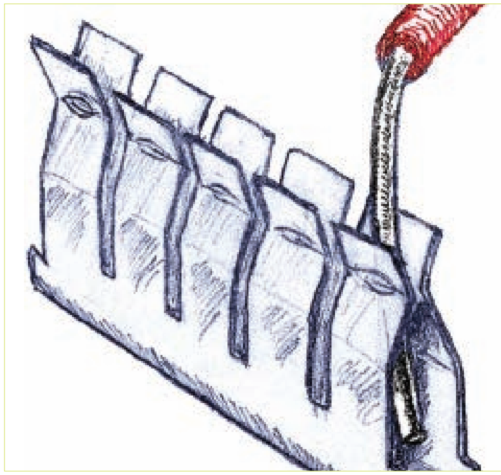

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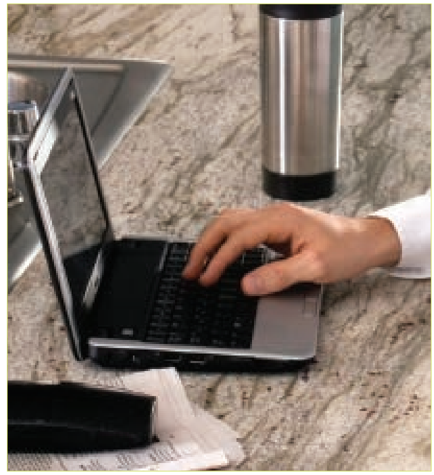

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Exclusive Online Content

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Check to see what's online this month for additional reading!

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Value Packs

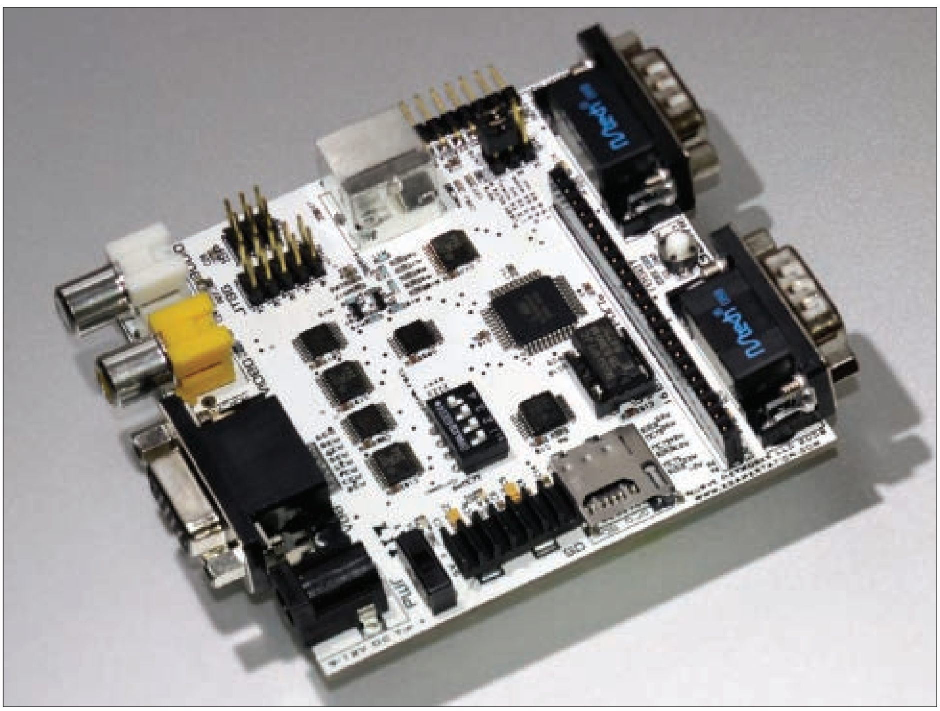
Value packs are en vogue in grocery stores, restaurants, and fast food outlets because they promise to deliver a lot for a little cash. The concept has been applied to electronics as well, with some success. When I think value packs in electronics, I think kits in general. I also know a few specific suppliers that provide exceptional economic and educational value, while also saving time and effort.

It's hard to beat the value provided by the various educational kits sold by Parallax (**www.parallax.com**). Over the past several years, I've purchased (with personal funds) virtually every kit and course the company offers. Want to explore sensors and signals? They have a great text and component package. How about robotics? The Stamp-based Boe-Bot and SumoBot kits are simple enough for a child to build and challenging enough for a robotics or microprocessor enthusiast of any age. Even the $5,000 Parallax QuadRover — the exception to my Parallax acquisitions — provides an economical platform for a college course on robotics or for a robotics club. If you've ever built a moderate-sized, wheeled robot from scratch, then you recognize that $5,000 is a bargain.

Another of my favorites is Nurve Networks (**www.gamestation.com**) which offers a variety of no-frills, value-packed game development hardware and software kits. The Hydra game development kit — based on the Parallax Propeller chip — is by far the most economical path to working with and understanding the operation of the eight-core chip. In the June '07 issue of *Nuts & Volts*, I described how to build an exergame with the Hydra kit using a mems sensor and a few dozen lines of SPIN code. By no frills, I mean that you get everything you need to start developing games, but no fancy enclosure, knobs, or other human interface niceties.

Nurve Networks' most recent addition to their game development kits — the XGameStation — maintains the tradition of providing a lot of hardware, software, and documentation for a little. The $140 kit is available in two flavors: an eight-bit AVR model (see photo) which I own, and a 16-bit PIC model. As with the Hydra kit, the impressive XGameStation provides one of the most economical means of working with the underlying microcontroller chip.

The single board XGameStation provides numerous I/O ports for audio, video, data, Flash micro SD card, keyboard, and more. In addition, my AVR-based system shipped with a gamepad controller, PC serial port converter, Atmel AVR ISP MKII Programmer, wall transformer power supply, 1 GB SD card, cables, DVD with software, and 325 page spiral bound manual. Could I have assembled the same components for less? Perhaps, if I found a single supplier to minimize postage and handling fees. But even then, I would have missed out on the manual and software, and would have likely had to settle for blinking LEDs instead of a video image for development feedback.



Is an XGameStation, Hydra, Boe-Bot, or other value pack for you? It depends. The downside of these and similar value packs or bundles is that you get a great deal — as long as you need or want everything that comes with a kit. If you like video games, want to explore the Hydra, PIC, or AVR microcontrollers, and don't own a programmer or peripherals, then either the Hydra or XGameStation is a no-brainer. There's also the issue of minimal disruption. I loved my XGameStation from the start, for example, simply because everything arrived in one box and I didn't have to tear apart other projects for parts.

Furthermore, I didn't have to hunt down specifics on the AVR chip or source code examples —

examples and documentation were either in the manual or on the DVD.

The advantage of working with a fully specified hardware configuration — that is, a kit — is that you can leverage the knowledge and skills of hundreds of other experimenters who have bought into the platform. Need to modify the optional gripper for your Boe-Bot? Check out the forum on the Parallax website. Someone has probably done it before and you can learn from his or her efforts. It's more difficult to post a question about a custom microprocessor platform and expect support without offering an exhaustive, accurate description of your setup.

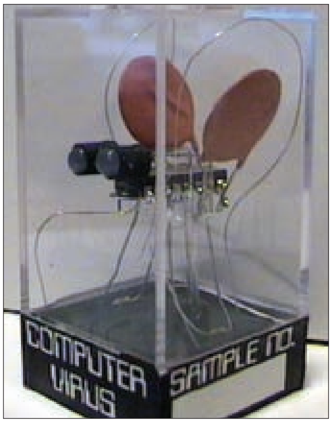
What are other value packs worth noting? Check out the vendors advertising in this magazine. I'm also impressed with by the educational electronics kits offered by Jameco (**www.jameco.com**) and robot kits by Lynxmotion (**www.lynxmotion.com**).

It's important to note that not all kits are value packs. While the kits that consist of a poly bag of ancient parts and a placement diagram may be economical, they are often the educational equivalent of empty calories. Look for kits with quality printed and electronic documentation — in English — and a significant user base. Check out the support and forum sites before you buy. It's comforting to know that help is available, if and when you need it. **NV**

READER FEEDBACK

NUTS AND VOLTS
EVERYTHING FOR ELECTRONICS

CATCHY COMPUTER VIRUS



Thank you for the Robot Art article in the April 09 issue. Here is a photo of my active "Computer Virus" that I designed and tried to market back in the 80s. The circuit detects changes in voltage fields (i.e., static electricity) and lights the LEDs either red or green, depending on the polarity of the charge. Every component of the Computer Virus is part of the circuit; the batteries are located in the base of the plastic box. No power switch is required. The device actually is useful in warning people that they are carrying a static charge.

Larry Burich
San Jose, CA

SPICEing IT UP

I enjoyed your article series on SPICE simulation. Is there a digital circuit version of Spice (I've heard of HSpice) available as freeware? Thanks.

Tom Campbell

Response: Thanks for the kind words! There are several similar variations of SPICE; here's a quote from the Wikipedia entry for SPICE at ***http://en.wikipedia.org/wiki/SPICE****):*

SPICE inspired and served as a basis for many other circuit simulation programs, in academia, in industry, and in commercial products. The first commercial version of SPICE was ISPICE, an interactive version on a timeshare service, (National CSS). The most prominent commercial versions of SPICE include HSPICE (now owned by Synopsys) and PSPICE (now owned by Cadence Design Systems). The academic spinoffs of SPICE include XSPICE, developed at Georgia Tech, which added mixed

continued on page 77

In the March 09 Personal Robotics column, Joe Grand's company name was listed incorrectly as Grand Design Studios. The actual name is Grand Idea Studio. Our apologies to Joe.
www.grandideastudio.com

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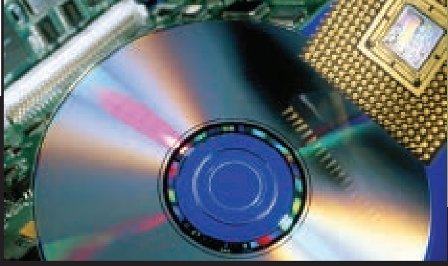


TECH KNOWLEDGEY 2009

EVENTS, ADVANCES, AND NEWS

■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

COLD FUSION … IT'S BAAACK!

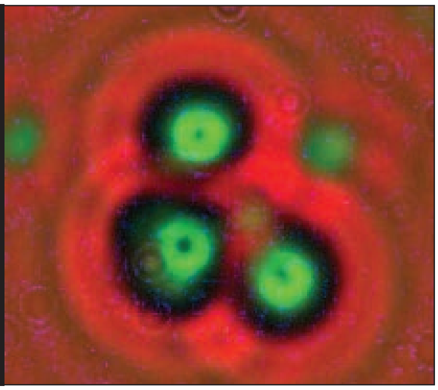


PHOTO COURTESY OF PAM BOSS, SPAWAR.

■ Pattern of triple tracks that scientists say is caused by high energy nuclear particles resulting from a nuclear reaction.

Back in 1989, electrochemists Martin Fleishmann and Stanley Pons created a worldwide sensation with their claim to have achieved room-temperature nuclear fusion in an experiment involving electrolysis of heavy water on a palladium electrode. Basically, the researchers reported the production of "excess heat" that could be explained only by nuclear processes. They also reported detecting some nuclear reaction by-products in the soup, including neutrons and tritium. Unfortunately, over the next few months and years, the noise and enthusiasm died out when no one was able to reproduce their results. The concept has been widely consigned to the dumpster of science, but some stalwart researchers have persisted in pursuing what is now known as low-energy nuclear reactions (LENRs). And wouldn't you know it? Some folks from the US Navy's Space and Naval Warfare Systems Center (SPAWAR) presented a paper at the American Chemical Society's latest National Meeting that brings LENRs back from the realm of impossible to that of merely improbable.

"Our finding is very significant," says study co-author and analytical chemist Pamela Mosier-Boss, Ph.D. "To our knowledge, this is the first scientific report of the production of highly energetic neutrons from an LENR device." In the new study, Mosier-Boss and colleagues inserted an electrode composed of nickel or gold wire into a solution of palladium chloride mixed with deuterium in a codeposition process. (A single atom of deuterium contains one neutron and one proton in its nucleus.) Passing an electric current through the solution created a reaction, and they used a special plastic material to capture and track whatever high energy particles were created.

The result was a pattern of "triple tracks" — three adjacent pits that seem to have split from a single point. The explanation is that the tracks were produced by the release of subatomic particles when neutrons struck the plastic. The neutrons, they theorize, were the result of nuclear reactions. "People have always asked 'Where's the neutrons?'" Mosier-Boss observed. "If you have fusion going on, then you have to have neutrons. We now have evidence that there are neutrons present in these LENR reactions."

Does this mean that cheap, unlimited, clean energy is on its way? Well, stay tuned. At least the dream lives on.

ROBOTECH SPAWNS HYDRO GENERATION

Some time ago, NASA Jet Propulsion Lab (JPL, **www.jpl.nasa.gov**) researchers developed a new way to power robotic underwater vehicles based on the use of ocean temperature differentials to create a high pressure fluid that is used to generate power. According to Yi Chao, a JPL scientist, "The trick was to find a special substance known as a phase change material that changes from a solid to a liquid as the temperature in the environment changes from cold to warm. When the material melts, it expands, compressing a central tube in which another liquid is stored. This liquid, now under high pressure, is used to generate electricity to charge the battery underwater." The prototype underwater glider is slated for testing this fall.

Not satisfied with thinking small, Chao and colleague Jack Jones have now proposed a spin-off that is essentially a scaled-up version that might be used to produce electricity on land. In the large-scale hydrokinetic energy transfer system, ocean tides, currents, and waves, as well as river flows, would provide the energy source to create the high pressure liquid. As the water turns underwater turbine blades, the rotor's rotational speed would be increased through a gearbox to drive a high pressure fluid pump. The high pressure fluid would be transported though flexible tubes to a larger pipe and then to an onshore hydroelectric power plant.

■ The flow of water current causes turbine blades to rotate, driving a high pressure fluid pump. The high pressure fluid then would be transported to onshore hydroelectric power plants.

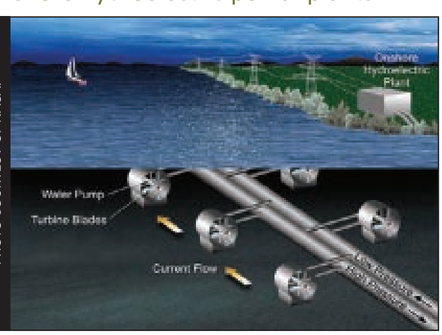


PHOTO COURTESY OF NASA.

Cited major advantages include minimizing environmental impact through the use of fresh water in a closed-cycle system, elimination of all submerged electrical components, and the ability to store the pressurized hydraulic energy in an elevated reservoir to allow demand-dependent electrical production.

Jones and Chao will be presenting details at the American Society of Mechanical Engineers Conference on Ocean, Offshore, and Arctic Engineering (**www.ooae.org**) in Honolulu, HI (May 31 to June 5), so drop in if you read this in time.

COMPUTERS AND NETWORKING

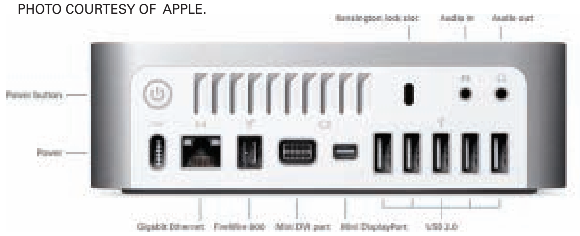
NEW MINI ARRIVES

It's been nearly two years since Apple updated its one and only product aimed at the low end of the computer market, but the 2009 Mac Mini is now available. Consistent with the company's pattern of adding features rather than lowering prices, the new model will run you $599 or $799, depending on whether you want 1 or 2 GB of memory (upgradable to 4 GB) and a 120 or 320 GB hard drive. Either way, it comes with a 2.0 GHz Intel Core 2 Duo processor, an 8x double-layer SuperDrive, and a NVIDIA GeForce 9400M GPU that boosts the Mini's graphics performance by up to 500 percent. And, as before, no display, keyboard, or mouse. Also new is the ability to drive two displays simultaneously, including the Apple LED Cinema Display or third-party products.

For connecting to the outside world, it features five USB ports and one FireWire 800. The company also points out that the Mini is the "world's most energy efficient desktop computer," consuming less than 13 W. Reviews have been largely positive, although it is noted that by the time you buy a monitor and add some RAM, you'll be back over $1,000. That brings it up to about the cost of an iMac, which starts at $1,199 with a 20 inch monitor, a 2.66 GHz processor, and the same other innards. But the 6.5 sq. in. box is pretty cool.

■ New Mini is faster and more graphics capable.

PHOTO COURTESY OF APPLE.



DON'T FEAR THE REAPER

■ Mr. Death can get you but not your digital assets, thanks to Legacy Locker.

If you (a) feel the reaper breathing down your neck and (b) want to pass on the contents of your online accounts, you may like the new service from Legacy Locker (**www.legacylocker.com**). You just enter your online account information (e.g., such as email addresses, photo sharing sites, and whatever requires a login) in a digital "locker." For each account, you assign a beneficiary who, in the event of your passing, will receive the asset electronically. Whereas it's doubtful that anyone will really want to pick up where you left off in Second Life or download that adult material you've been hiding from the kids, it might be thoughtful to give your loved ones a whack at some major online purchases before your credit card accounts are shut down.

In addition, the service lets you create "legacy letters" to be delivered to specific people at the appropriate time. I'm thinking something like, "Hey, Boss. Remember those weekends when you thought your wife was visiting her Aunt Helen in Terra Haute? Well ...

"If you think you're going to hang around for 10 years or more, you can save money with the $299.99 one-time fee. Otherwise, the best bet is the $29.99 annual option. Free trial accounts are available if you can't make up your mind yet.

RECIPES FOR THE REST OF US

Sure, some people have pantries and refrigerators chock full of everything a gourmet cook could need. But some of us are ingredientally challenged and constantly ask, "What the heck can I make for dinner tonight out of this?" Well, rejoice, because now we have a new search engine called Super Cook (**www.supercook.com**). All you have to do is enter the names of whatever edible substances you have on hand, and Super Cook will come up with recipes for dishes you can make from them. It also brings up dishes that are almost doable and lists the missing ingredients.

Alas, it can't work magic if you haven't been to the store since Thanksgiving. Last night, I took inventory and entered bacon, bologna, anchovies, Cheez Whiz, and family dog. It rejected the dog (which actually does smell like he's past the expiration date) but informed me that I can make Asparagus Wrapped in Streaky Bacon if I can locate the asparagus somewhere. Mysteriously, it also offered Cherry Rolls, advising that the only lacking ingredient is maraschino cherries. There may still be some

bugs in the site (which also didn't recognize "bugs").

CIRCUITS AND DEVICES

CARE TO POUNCE ON A P.U.M.A.?

The Segway/GM P.U.M.A. prototype: future or fantasy?

In December of 2001, the Segway (**www.segway.com**) two-wheeled scooter was introduced, having been the subject of much speculation and unprecedented hype. It's inventor, Dean Kamen, was hailed as the next Henry Ford, riding high on marketing studies that predicted sales of 31 million units during its first decade or so. ("The Segway," he predicted, would "be to the car what the car was to the horse and buggy.") Investors voiced expectations that the company would pass the $1 billion sales level faster than any company in history. Alas, in reality, only about 23,500 were sold in the first six years, and sales dropped off afterward because of recalls, mechanical and safety problems, and the public's desire to avoid looking like a Silicon Valley dork. But the concept has evolved, and now Segway has announced Project P.U.M.A. (for Personal Urban Mobility and Accessibility) which promises a two-seater vehicle with a top speed of somewhere between 25 and 30 mph (40 to 56 kph) and 25 to 35 miles range on a single charge. Segway has cleverly teamed up with that monster of a profit machine, General Motors, for the venture, allowing it to offer OnStar in the little electric buggies and probably latch onto some of those bailout gigabucks. Will the vehicle — currently a prototype — ever make it to the streets? Well, it's too big and fast for sidewalks, too delicate to be operated in real traffic, and too fast for bike lanes. Take a guess. By the way, if you are under the impression that the original Segway scooter is based on esoteric and difficult-to-comprehend technologies, check out **www.tlb.org/scooter.html**. Trevor Blackwell will show you how to build one (minus most of the safety features) for about $1,700 worth of readily available parts.

LOW LEAKAGE VARISTORS

AVX Corporation (**www.avx.com**) has introduced a zinc oxide-based varistor series that exhibits a

INDUSTRY AND THE PROFESSION

CHIP SALES BOTTOMING?

According to the latest report from the Semiconductor Industry Association (**www.sia-online.org**), worldwide sales of semiconductors totaled $14.2 billion in February, a decline of 30.4 percent from 2008. February sales were also down 7.6 percent from January.

"The global semiconductor industry is going through one of the steepest corrections in its history," said SIA President George Scalise. "While it would be premature to conclude that the sales decline has hit bottom, there are some indications that the rate of decline has moderated from the final quarter of 2008. The world's two largest foundry manufacturers have recently reported slight improvements in factory utilization rates, albeit at levels well below those of a year ago ... Demand for semiconductors is likely to continue well below 2008 levels for the next few quarters, with a gradual recovery to follow as the global economy recovers," he concluded.

2M ARTICLES NOW AVAILABLE

Last month, the IEEE (**www.ieee.org**) announced the addition of the two millionth article to be available on its IEEE Xplore® digital library (**ieeexplore.ieee.org**). The article, "Intelligent Packet Dropping for Optimal Energy-Delay Trade-offs in Wireless Downlinks," is written by IEEE Senior Member Michael J. Neely, assistant professor at the Communication Sciences Institute, which is part of the Electrical Engineering Department at the University of Southern California, Los Angeles. Neely's article discusses how implementing an innovative algorithm into a wireless network can fundamentally change the efficiency of wireless transmitters, which would be beneficial in prolonging battery life without adversely affecting performance. IEEE Xplore — which includes content from IEEE journals and magazines going back as far as the year 1913 — is billed as a comprehensive online database of current and past research from many industries, including aerospace and defense, automotive, computing, medical devices, nanotechnology, petroleum and natural gas, power and energy, semiconductors, and telecommunications. Complete access is free only to IEEE members, but nonmembers can search and access abstracts and purchase full PDF documents individually. The Neely article is also downloadable from **www.webbooks.net/freestuff/neely.pdf**.

low leakage current of 2A maximum. Designated the UltraGuard Series, the multilayer ceramic devices feature nonlinear, bidirectional voltage-current characteristics similar to back-to-back zener diodes and an EMC (electromagnetic compatibility) capacitor in parallel. According to AVX, "Our UltraGuard Series offers many electrical advantages over zener diodes, including better repetitive strike capability, higher inrush current capability, faster turn-on-time, and inherent EMI/RFI attenuation. Furthermore, the varistors are significantly smaller, saving important board space."

The UltraGuard Series comes in discrete chips available in 0402, 0603, and 0805 sizes; two-element packages in 0405 and 0508 sizes; and four-element 0612 packages. Low and high capacitance versions are offered ranging from 40 through to 3,000 pF. The devices are suitable for transient protection applications where power consumption is a concern. These include high clock speed ICs, battery-operated devices, backlit displays, medical and instrumentation applications, low voltage power conversion circuits, and power supervisory chip sets. Additional applications include laser diodes, laser diode drivers, and serializer and deserializer devices. **NV**

■ BY FRED EADY

INTO THE GUTS OF USB DRIVERS

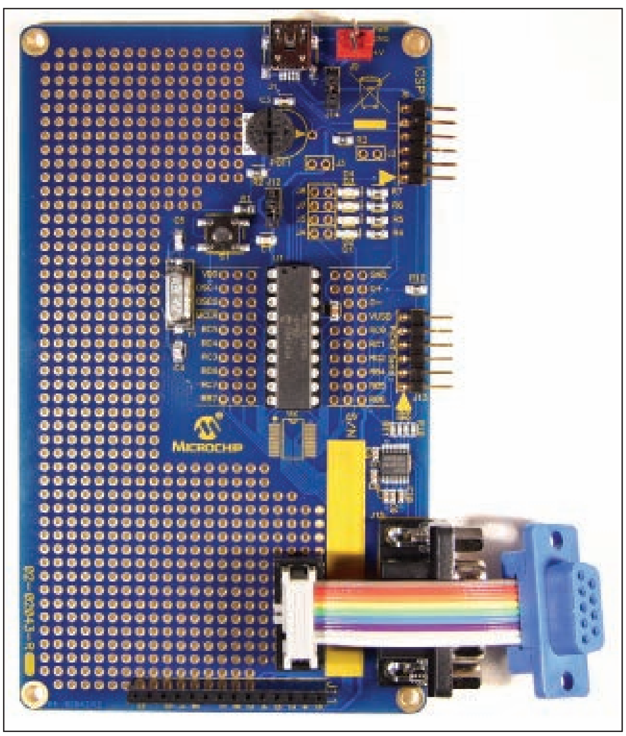
WHEN IT COMES TO REPLACING A LEGACY RS-232 INTERFACE WITH USB, we've done it with a Silicon Laboratories CP2102 USB-to-UART bridge controller. We've also done it with their CP2103. We've even done it with an FTDI FT232R USB UART IC. Well, now it's time to do it again. This time, with a Microchip PIC18F14K50 USB Flash microcontroller.

The FTDI and Silicon Laboratories dedicated USB interface ICs are designed to be drop-in replacements for legacy RS-232 converter ICs. Even though the aforementioned USB-to-UART parts are dedicated in their missions, they do have the ability to be programmed to a certain extent. The Microchip PIC18F14K50 can also be dedicated to a USB mission. Note that I said "can be." In reality, the 18F14K50 is a standard PIC microcontroller with USB enhancements. For instance, if you decided that the PIC18F14K50 was just the microcontroller you needed for a non-USB application, it's USB interface pins can be configured as standard PIC input pins. On the other hand, if you need a fully programmable USB-to-UART bridge that can also run an application, the PIC18F14K50 is your huckleberry.

THE PIC18F14K50

On the USB side, the PIC18F14K50 is equipped with an internal USB Version 2.0 SIE (Serial Interface Engine) which supports USB low speed (1.5 Mbps) and USB full speed (12 Mbps) operation. Support for 16 endpoints is backed up by a 256-byte Dual Access RAM. If SIE and endpoint concepts aren't already in your Design Cycle, don't worry about them right now. By the time we've finished this month's discussion, you'll have obtained that knowledge.

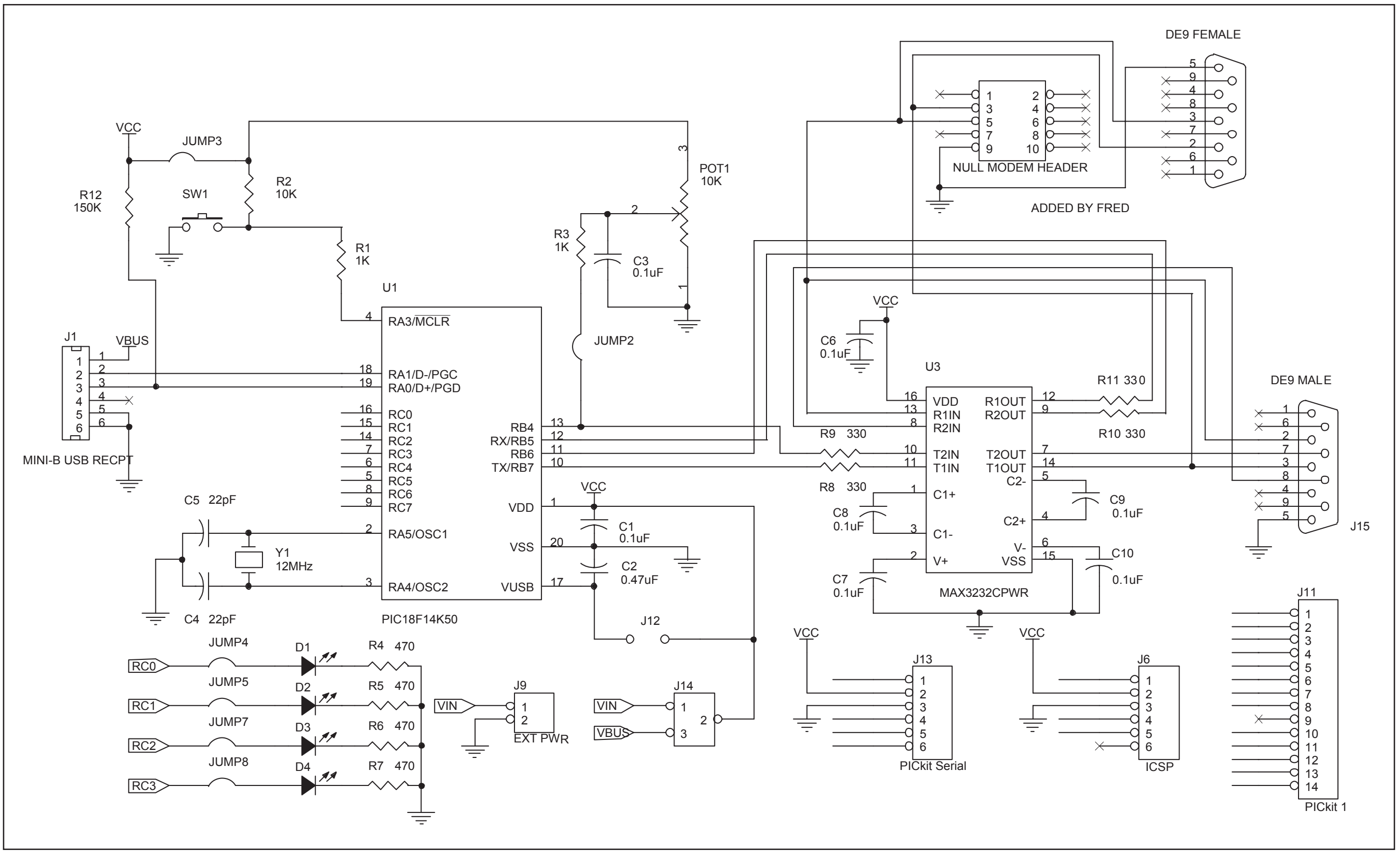
The PIC18F14K50's attributes include I/O pins that can source and sink 25 mA, an Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART), a 10-bit analog to digital converter, a pair of analog comparators, and an on-chip voltage reference. Although the PIC18F14K50 can be powered with a 5.0 volt supply, the PIC18F14K50 silicon is designed to operate between 3.3 and 3.6 volts only. Thus, the PIC18F14K50 contains an internal 3.2 volt regulator which allows the silicon to operate safely at 3.2 volts while the I/O subsystem can interface with a 5.0 volt system. The PIC does not contain an internal voltage regulator as it cannot be powered with a 5.0 volt power supply. The LF variant is designed to operate exclusively in 3.0 volt systems.



■ PHOTO 1. The ultimate goal is to put this PIC18F14K50 to work as a USB-to-UART bridge. The Low Pin Count USB Development Kit provides everything we will need to accomplish the task. The pad area below the PIC18F14K50 DIP enables us to mount the SSOP version of the PIC18F14K50. I added the 10-pin header which is wired as a null modem allowing the dev board to interface to my Lenovo Netbook as a DCE RS-232 device.

SUPPORTING THE PIC18F14K50 WITH HARDWARE

Schematic 1 is a graphic representation of the Low Pin Count USB Development Kit, which you can buy for around $40. This Kit consists of a fully populated printed circuit board (PCB), an unpopulated low pin count PCB, an SOIC version of the PIC18F14K50 on a debug header, and all of the example code and documentation you'll need to get a PIC18F14K50-based USB device up and running. The kit we will be



■ SCHEMATIC 1. Keep in mind that this is the default configuration of the Low Pin Count USB Development Kit. The jumpers are actually traces on the printed circuit board. Leave J12 open and jumper pins 2 and 3 of J14 for bus-powered operation. The DCE interface components make up my custom null modem arrangement and are not part of the original dev kit.

discussing is smiling for the camera in **Photo 1**.

If you strip away all of the eye candy in Schematic 1, you'll see that the PIC18F14K50 only requires a crystal, the crystal's associated capacitors, a power supply bypass capacitor, a pullup resistor, and a VUSB filter capacitor for proper bus-powered operation. If you want to run the PIC in self-powered mode, you must provide the external 3.3 volt power source and place a jumper at J12.

For low speed operation, the PIC's USB module must be clocked at 6 MHz. The clock source must originate from its primary oscillator which can be driven by a crystal or an external oscillator. A 12 MHz clock source can also be employed as the PIC18F14K50's clock mechanism has the ability to divide the incoming clock source by two. The 12 MHz crystal in the low pin count kit design allows us to run at low speed or full speed. Full speed operation requires a 48 MHz USB clock. This USB clock is derived from the 12 MHz clock input, which is fed through a 4x PLL-based frequency multiplier to provide a 48 MHz clock to the USB module. Meanwhile, with a 12 MHz clock input, the PIC18F14K50's system clock can be configured to run between 3 MHz and 48 MHz in low speed mode and between 12 MHz and 48 MHz in full speed mode.

Placing a jumper between pins 2 and 3 of J14 and leaving jumper J12 open places the PIC18F14K50 in bus-powered mode. In this mode, we only need to install the 0.47 µF filter capacitor across the VUSB pin to ground. Should you decide to place it in self-powered mode, you would feed 3.3 volts into J9 pin 1 and place the J14 jumper between pins 1 and 2 and jumper J12. In either mode, the ceramic filter capacitor must always be present at the VUSB pin.

SUPPORTING THE PIC18F14K50 WITH FIRMWARE

Our USB-to-UART application code is heavily

■ PHOTO 2. The Ellisys USB Explorer 200 USB protocol analyzer is capable of capturing and decoding low speed, full speed, and high speed USB data streams. Once the capture is saved as a file, you can use the Ellisys USB Analysis Software to view the capture without the aid of the Ellisys hardware.

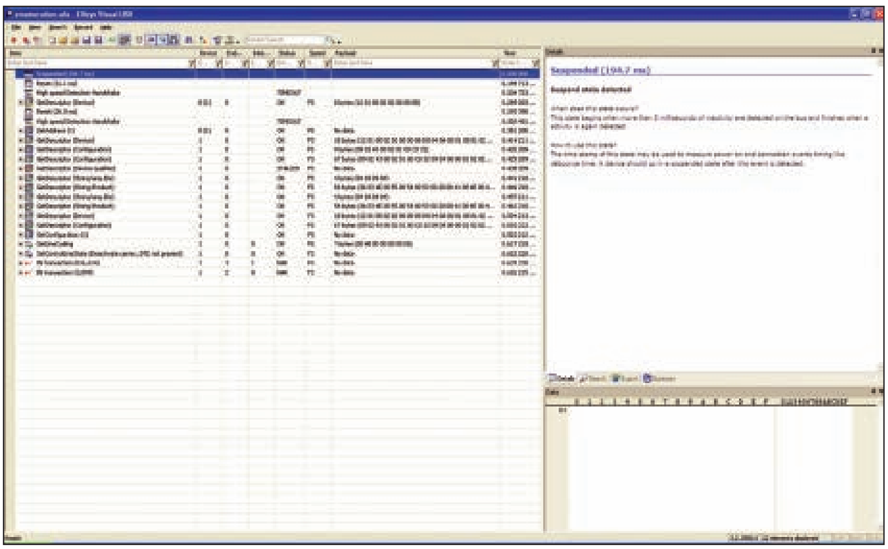
influenced by the Microchip USB device firmware framework. Currently, the framework is officially supported by Microchip's family of C compilers. However, HI-TECH Software is now a fully owned subsidiary of Microchip and according to those in the know, you'll see a HI-TECH port of the firmware framework soon.

The framework is a free development tool that is actually a library of USB routines we can use to build custom USB applications. The idea behind the structure of the framework is to allow us to build our application in a separate directory and place calls to the supporting USB framework routines which are organized logically in a number of framework directories.

The operation of the firmware framework hinges on an endless loop contained within the *main* function of the application. To allow every USB and user task to be serviced, the application must be written to adhere to the rules associated with a cooperative multitasking environment. For instance, our USB-to-UART application will consist of a *main* function which places a call to service USB tasks (USBDeviceTasks) and the user tasks (ProcessIO).

The Microchip framework takes care of the down and dirty USB work for us. If you're interested in how all of the USB code fits together, the source code is very well documented. Taking the time to read the comments will guide you step by step through the various USB tasks and configuration tables. We're not going to go into the detail associated with the USB stack in this discussion. However, we are going to take a detailed look at the USB data stream with the help of the Ellisys USB Explorer USB 2.0 protocol analyzer you see in **Photo 2**.

■ SCREENSHOT 1. Thanks to the Ellisys USB Explorer 200 and companion software, we can examine each and every byte of a USB data stream. In addition to decoding the USB data stream, the Ellisys USB Analysis Software also points you to associated explanations in the USB Specification.

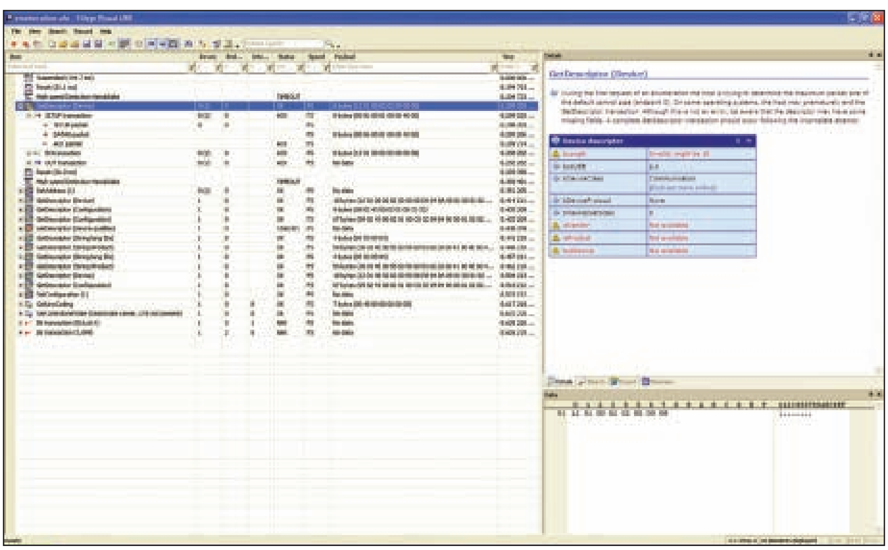


ENUMERATION

The process of enumeration is performed every time a USB device is connected to a host. Enumeration is the time in which the host determines what type of device has been connected to the USB bus. The USB host also uses the enumeration time to gather information needed to service the newly connected device. Once enough information has been collected, the host will assign an address to the device and select the proper device driver to enable the transfer of data.

Screenshot 1 is a capture of a PIC18F14K50 USB-to-UART enumeration sequence. You can view the details of this capture by downloading a copy of the Ellisys USB Analysis Software from their website. I've included a copy of the enumeration capture file (enumeration.ufo) in the download package on the *Nuts & Volts* website (**www.nutsvolts.com**).

After detecting a new device on the bus, the first thing the host (or hub) does is to give the device time to stabilize. The host will wait for a minimum of 100 ms which should be enough time for the device's power to stabilize. At this point, the host takes no chances and issues a reset to the newly discovered device. The reset will force the device into a default state which results in the device answering to default device address zero. Take a careful look at the trace and note that the host is also attempting to determine if the device can communicate at high speed. In the case of our PIC18F14K50, the chirps in the capture will never be positively acknowledged



■ SCREENSHOT 2. A descriptor is nothing more than a collection of data describing aspects of the USB device. The host requests data from various types of descriptors that enable it to properly insert a USB device on the bus.

as the PIC can't run at high speed.

Once in the default state, the device must be able to communicate using its endpoint 0. If you consult the USB 2.0 Specification, you'll find that a device endpoint is defined as a source or sink of information in a communication flow between the host and device. In other words, a device endpoint is a buffer that sits at the device end of the communications link and acts as an interface between the device's hardware and firmware. During enumeration, endpoint 0 is responsible for receiving all of the device's control and status requests. The host communicates to the device endpoints via what is called a pipe. A pipe is no more than a logical connection between the host and device endpoints.

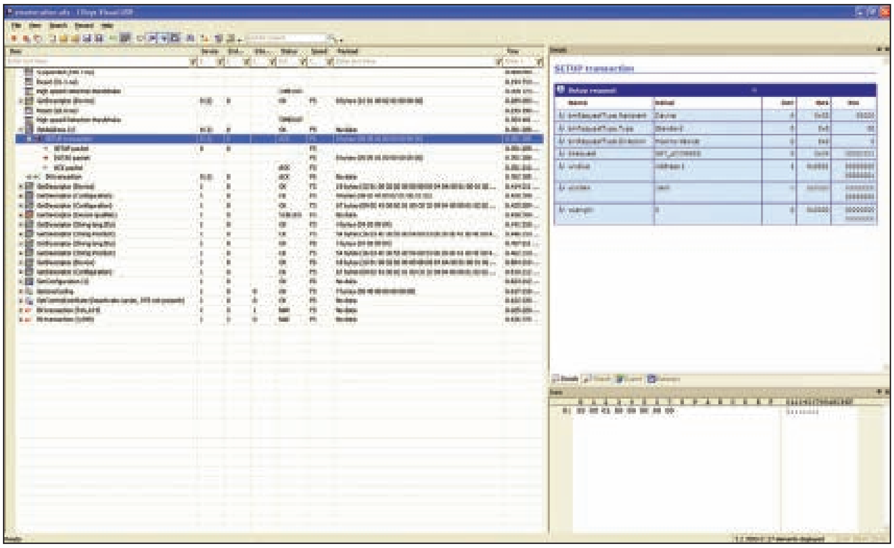
Before any serious data transfers can occur, the host needs to know the maximum packet size that can be accepted by the device's endpoint 0. So, as you can see in **Screenshot 2**, the host issues a GetDescriptor command asking for the first 64 bytes of the Device Descriptor. The endpoint 0 maximum packet size information is held in the eighth byte of the Device Descriptor. After reading that byte, the host has all it needs to continue and issues yet another reset.

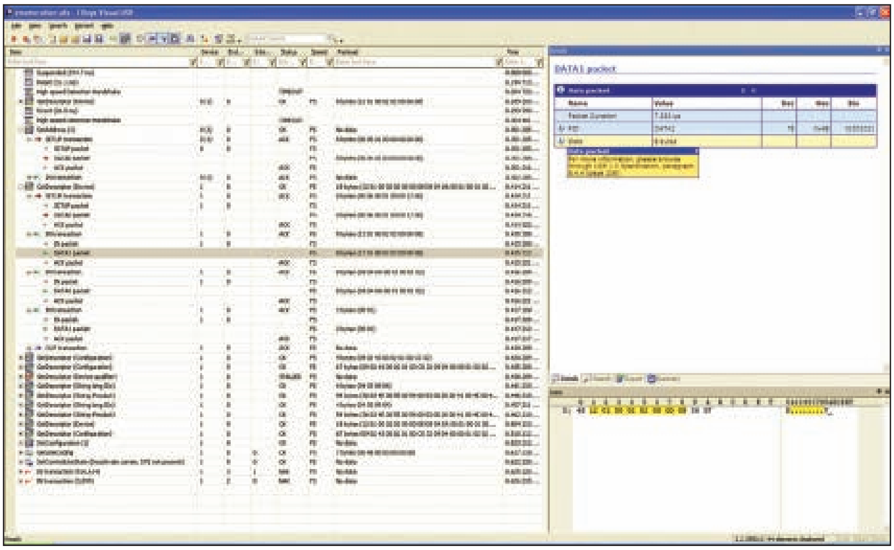
At this point, the host has established a communications session with the device using the default device address of zero. The host also has enough information about the device's endpoint 0 to assign an address to the device. **Screenshot 3** highlights the command bytes sent by the host to logically address the device. After assigning the device address, the host requests the entire contents (18 bytes) of the Device Descriptor. A couple of items the host will need reside at offsets 8 and 10 of the Device Descriptor. Offset 8 (relative to zero) contains the Vendor ID (VID) which is assigned by the USB-IF (USB Implementer's Forum, Inc.). The PID (Product ID) resides at offset 10. Unlike the VID, the PID is assigned by the device manufacturer. The VID and PID are used to help the host select the correct driver for the device. Here's the PIC18F14K50's USB-to-UART Device Descriptor, which you can find in *usb_descriptors.c*:

```
/* Device Descriptor */
ROM USB_DEVICE_DESCRIPTOR device_dsc=
{
     0x12, // Size of this descriptor
     USB_DESCRIPTOR_DEVICE,     // type
     0x0200, // Spec Release Number
     CDC_DEVICE,         // Class Code
     0x00,               // Subclass code
     0x00,               // Protocol code
     USB_EP0_BUFF_SIZE,       // Max packet size
     0x4D8,              // Vendor ID
     0x000A,             // Product ID:CDC RS-232
     0x0001,             // Device release number
     0x01,               // Manuf string index
     0x02,               // Product string index
     0x00,               // Device SN string index
     0x01                // Num of configurations
};
```

Here's the *usb_config.h* value referenced in the Device Descriptor:

■ SCREENSHOT 3. This capture shows the host assigning an address to the device. I suggest using your copy of this capture and opening up the detail to see what is really going on behind the scenes.





■ SCREENSHOT 4. I opened up the GetDescriptor command in this capture to show the 18 bytes of the Device Descriptor changing hands. The first byte of a Descriptor always represents the length of the Descriptor. The Descriptor Type is always identified by the second byte. The Details window points us to paragraph 8.4.4 on page 206 of the USB 2.0 Specification for more information about the eight payload bytes in this packet.

```
// Valid Options: 8, 16, 32, or 64 bytes.
// Using larger options take more SRAM, but
// does not provide much advantage in most types
// of applications.  Exceptions to this, are
// applications that use EP0 IN or OUT for
// sending large amounts of application related
// data.
#define USB_EP0_BUFF_SIZE 8
```

Notice also that our USB-to-UART device is classed as a CDC device. CDC is short for Communications Device Class and is usually associated with analog modems, telephones, and other similar networking devices. Since we're deploying the PIC18F14K50 as a USB-to-UART, it logically falls into the CDC class.

After consuming the entire Device Descriptor, the host is still hungry for information and requests the first nine bytes of the device's Configuration Descriptor. The trace for this activity is captured for you in **Screenshot 5** and this is the CDC Configuration Descriptor we will use:

```
ROM BYTE configDescriptor1[]={
     /* Configuration Descriptor */
     0x09,     //sizeof(USB_CFG_DSC),
               // Size of this descriptor
     USB_DESCRIPTOR_CONFIGURATION,    // type
     67,0,     // Total datalen for this cfg
     2,        // Num of interfaces in this cfg
     1,        // Idx value of this configuration
     0,        // Configuration string index
     _DEFAULT | _SELF,       // Attributes
     50        // Max power consumption (2X mA)
};
```

The host is in search of the total length of data for this configuration which you can see is 67 bytes. Here's how the attributes are defined in *usb_device.h*:

```
/* Configuration Attributes */
//Default Value (Bit 7 is set)
#define _DEFAULT     (0x01<<7)
//Self-powered (Supports if set)
#define _SELF (0x01<<6)     //Remote Wakeup
(Supports if set)
#define _RWU (0x01<<5)
#define _HNP (0x01<<1)
#define _SRP  (0x01)
```

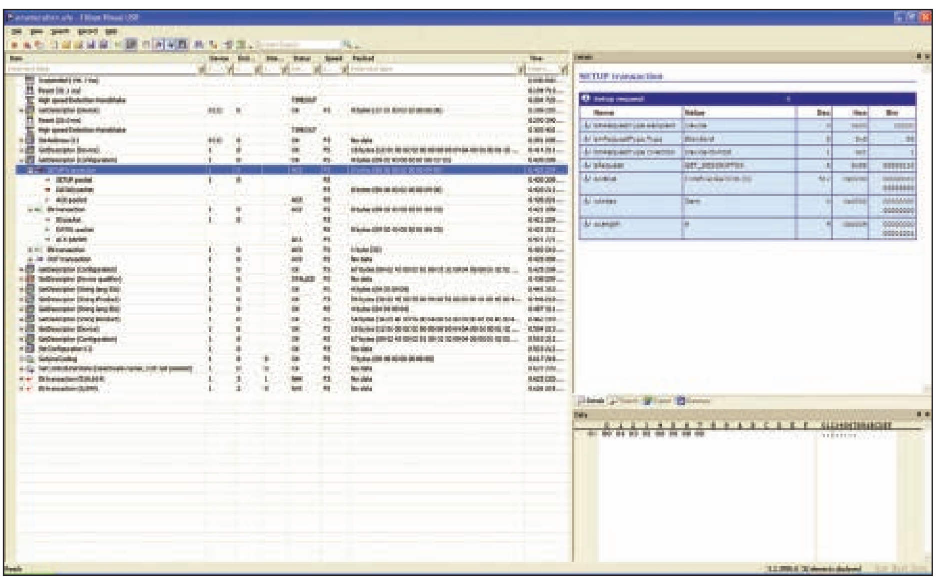
Keep in mind that we have been tracking the enumeration process as it is being performed by a Windows XP host. The next thing the host will do is request 255 bytes of the Configuration Descriptor. This is reflected in the *enumeration.ufo* capture. The 255 byte request is followed by a succession of String Descriptor requests. To give you an idea of what a String Descriptor is, I modified Microchip's original Product String as follows:

```
//Product string descriptor
ROM struct{BYTE bLength; BYTE bDscType; WORD
string[26];} sd002={
sizeof(sd002),USB_DESCRIPTOR_STRING,
//ORIGINAL STRING
//{'C','D','C',' ','R','S','-','2','3','2',' ',
//'E','m','u','l','a','t','i','o','n','
//',' D','e','m','o'}};
//FRED'S STRING
{'N','U','T','S',' ','A','N','D',' ','V','O','L',
'T','S',' ','U','S','B','-','T','O','-
','U','A','R','T'}
```

You'll find my modified Product String in the Windows XP Device Manager. Just view the properties of the Microchip COM port driver and you'll notice that the *Location* entry is followed by my modified Product String.

Once all of the necessary String Descriptors have been accessed, the host will request a driver for our device. Note that before setting the configuration of our CDC Serial Emulator device, the host will ask for the Device and Configuration Descriptors once again. At this point, the host and device are ready to rock and roll.

The CDC Serial Emulator program looks for data coming in from the RS-232 connection and routes any incoming data to the USB buffer for transmission over the USB bus. Obviously, it performs the same tasks with the USB interface being the input and the RS-232 interface as the target output. All of the buffer-to-buffer housekeeping is done within the CDC Serial Emulator application. The *usb_function_cdc.c* source file contains the bulk of the CDC Serial Emulator tasks.

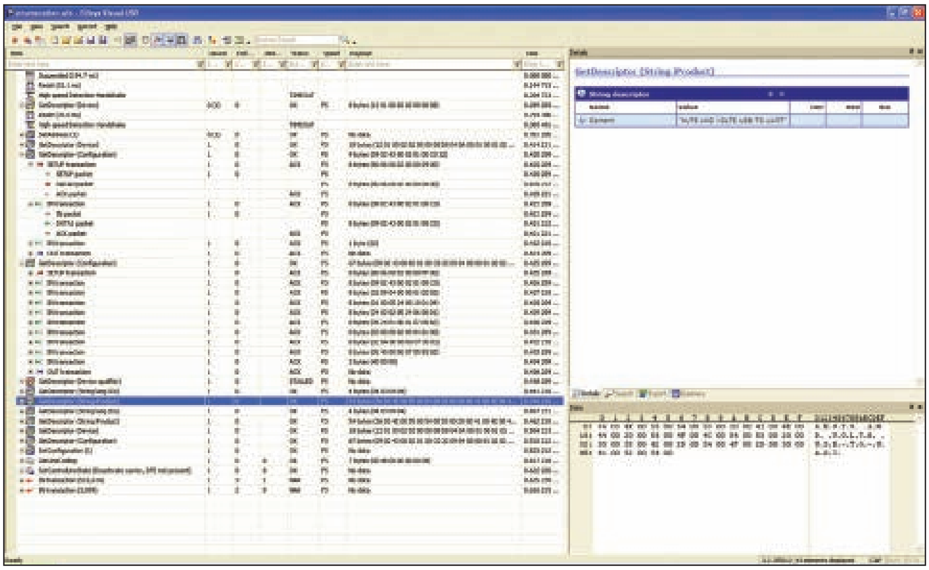


■ SCREENSHOT 5.The host is pumping the device for every piece of information it can in any way it can. Here, the host is seeking the total amount of data contained within this configuration which happens to be 0x0043 (67 decimal) bytes.

SOURCES

Microchip — www.microchip.com
Microchip USB Device Firmware Framework; Low Pin Count USB Development Kit; PICkit2; PICkit3; C18 C Compiler; PIC18F14K50

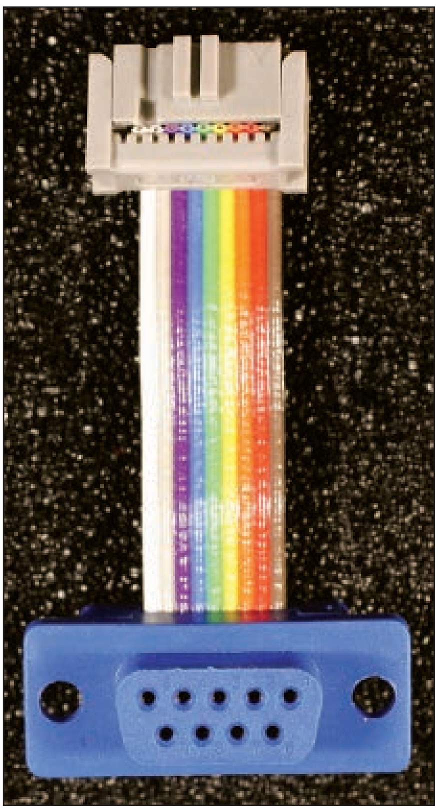
Ellisys — www.ellisys.com
Ellisys USB Explorer 200 USB Protocol Analyzer; Ellisys USB Analysis Software



■ SCREENSHOT 6. The strings are used in various places for human benefit. For instance, if you look at the COM port properties entry in Device Manager, you'll find the "NUTS AND VOLTS USB-TO-UART" string behind the Location description under the General tab.

JUST ANOTHER WALK IN THE USB PARK

Believe it or not, you don't have to write a single line of code to build a USB-to-UART bridge with the PIC18F14K50. All of the code we have discussed — with the exception of my custom Product String — is contained within a CDC example project that is bundled into the firmware framework. So, we can build up our own unique version of the low pin count kit and simply load the CDC code into our PIC18F14K50 using a PICkit2 or PICkit3 and BOOM! A USB-to-UART bridge comes to life. In this respect, the PIC18F14K50 also qualifies as a "drop-in replacement" for legacy RS-232 interfaces.



■ PHOTO 3. This is a simple straight-thru affair. Note the location of the pin 1 key and the socket polarization tab on the 10-pin plug versus the orientation of the DE-9 IDC connector. No cable twisting is necessary. However, note that the ribbon cable is stripped to nine strands to mate with the DE-9 IDC connector.

If you plan to interface to a PC COM port, you'll need a female DE9 connector for the null modem interface. As you can see in **Photo 3**, I used a piece of ribbon cable and a couple of common IDC connectors to assemble my DCE interface.

Scratch another notch into the handle of your USB gun. You've just added another USB device to your Design Cycle. **NV**

CONTACT THE AUTHOR

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■ BY LOUIS E. FRENZEL W5LEF

SMART PHONES LEADING CELLULAR GROWTH

Your Cell Phone is Morphing into a Computer

If you had the hard choice of keeping only one of the following, which would it be: TV, cell phone, or the Internet? In a recent survey I took, most people said they would give up the TV first by about 75%, the cell phone next by 22%, and the Internet by 3%. Today, however, if you have the right cell phone, you get the Internet with it.

The cell phone has become a must-have item in our modern life. You pick it up when you grab your car keys and wallet or purse every day. It has become the don't-leave-home-without-it item of the century. The cell phone is clearly addictive technology, in a good sort of way.

The reason for this clear addiction to our cell phones is that we love to communicate. Not just for emergencies but because we just like to stay in touch. Have you ever listened in on the cell phone calls people make right after a plane lands? Most are worthless and insipid but people love to just say "I'm here" or some such thing. The cell phone has made us all communicate more; not only personally, but within companies and other organizations. Many groups can point to productivity boosts of 15% or more thanks to cell phones.

■ FIGURE 1. The Apple iPhone 3G. While the Palm phone kicked off the smartphone idea, it was the iPhone that is responsible for the recent surge in subscriber interest and multiple new competing models.

While the cell phone is just a sophisticated two-way radio that gives us that instant communication we crave, it is gaining even more attention thanks to the many exciting features being added. Color screens are the norm as is a camera and texting capability. But now, phones have email, Wi-Fi, Internet access, video, and GPS.

Phones that embody all these features are referred to as smartphones. These are the PDAs of today. While they make up only about 23% of the total cell phones out there right now, they are growing in number. If you do not have one now, you probably will in the future.

THE GROWING CELLULAR BUSINESS

Think about this. Over 1.3 billion cell phones were sold worldwide in 2008. China leads the world in total cell phone subscribers with over 350 million, but the US is close behind in second with over 270 million subscribers in 2008. That is about a 6% growth rate over 2007. That growth won't be as much this year due to the economic downturn but overall it is expected to still be a reasonable growth in bad times. The US cell phone industry generated over $148 billion in 2008 according to the CTIA, the US cell phone manufacturer's organization. They do a survey twice a year to check on the industry status.

The really amazing statistic to come out of that survey is that text message traffic exploded. In 2008, the cell phone carriers handled over one trillion (yes, with a T) text messages. Amazing really, but still growing.

My specialization is wireless, particularly cell phones. So, to keep myself up to date on this technology, I attend two major conferences each year. One is the Mobile World Congress, a huge show of 40,000+ in Barcelona, Spain put on by the GSM Association in February. The second is the CTIA, the Wireless Association show in Las Vegas in April. Both bring in all the big wheels of the industry to discuss trends, issues, problems, and potential business options. It is at these conferences

where all the new, hot wireless products are introduced, the handsets, as well as cell site basestations, and other infrastructure equipment. Here are a few of those trends and issues I've seen so far this year.

SMARTPHONES ON THE RISE

Probably the first smartphone was the Palm Treo. Palm, as you recall, was the inventor of the personal digital assistant (PDA). The PDA let you maintain a calendar, phone book, take notes, and do lots of other organizing chores we usually do on paper. They were the hot item of the day. Then, Palm put a cell phone in one and the smartphone race was on. The Palm was popular especially with the big company crowd as it was a real productivity booster (it was also pretty cool to have one).

Another early smartphone was the RIM BlackBerry. Its innovative push email feature put it in a class by itself. However, the Palm and BlackBerry phones remained a small percentage of all cell phones. They were expensive and their data capability was poor compared to today's standards. Other manufacturers began putting cameras and MP3 players into phones and texting became the hot application. All these things lead up to the phones that have every feature. Then along came the Apple iPhone in 2007 (**Figure 1**).

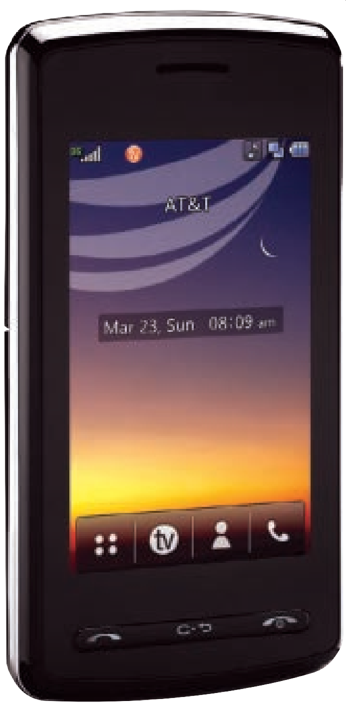
Smartphones like the iPhone have almost everything you can imagine. These include (as a minimum) a camera, short message service (SMS), email, Internet access, Wi-Fi connectivity, Bluetooth for head sets, a music player like iPod, GPS navigation, and in most cases some video capability. What more can you ask for? The iPhone made this category of phone even more desirable, but it also made it more affordable. The result: millions sold.

The iPhone phenomenon set off a wave of smartphone development that has been impressive. Now almost every major manufacturer has at least one phone in this category. The largest cell phone manufacturer (Nokia) has numerous models. So does the number two supplier of handsets (Samsung). The Korean and Chinese handset manufacturers led the way with dozens of models from LG, HTC, and others. Sadly, the once leading US manufacturer of handsets (Motorola) has slipped in this category after leading the pack a few years ago with their Q phone and almost smartphone called the Razr. Hopefully, we will see them come back. Apple and RIM still lead the smartphone pack with continuous upgrades to the iPhone and BlackBerry models.

Better technology has allowed all those features to exist with livable battery life. Just think about it. How many radios are really inside? There is the cell phone radio itself which, in most cases, is a multi-band radio, Bluetooth transceiver, Wi-Fi transceiver, and the GPS receiver. And don't forget, you need a different antenna for each one. Now think of all that jammed into the tiny handsets common today and you can begin to appreciate the technology even more.

TOUCH SCREENS ARE IN VOGUE

One thing the iPhone did is make touch screens popular. Instead of a keyboard, you simply touch the icons and virtual keyboards. Frankly, I do not like touch screens but I have gotten used to it on my iPhone. (I make lots of typos but I keep wondering if it is just me or the blasted keyboard.) The touch screen phenomenon has reached virtually every smartphone today. Thankfully, there are still some smartphones sporting a more traditional QWERTY keyboard.



■ FIGURE 2. The LG Electronics Vu CU920, an example of a cell phone that has mobile TV.

MORE DATA APPS

The big movement that helped create the smartphone is now doing the same with non-voice applications. The most popular is texting. Almost everyone does it now, but the teens and young adults still dominate this category. Email is also very popular — BlackBerry started this. Then, of course, is Internet access. Browsing and accessing stuff on the web can be done even though the small screen makes it difficult. According to the Wi-Fi Alliance, approximately 77% of smartphones have Wi-Fi access. That means when you hit an access point in a company or a hot spot, you can connect to the Internet and email that way instead of through the cellular network. And don't forget video. With most smartphones, you can watch YouTube and other video services over the network.

To make data applications practical, the data speed has to be reasonably fast. People have become accustomed to high speed Internet access so they expect the same from their smartphone. It is harder to do wirelessly, however. No one wants to wait for email to download or tolerate a jerky low res video so, year after year the cellular carriers have managed to boost data rates from below 100 kbps to over 2 Mbps in some instances. Even higher data rates are on the way.

THE RADIO TECHNOLOGY

Radio technology in cell phones is classified by generations. The first generation was analog; the second

generation was digital. We are now in the third generation (3G), headed toward 4G. Each new generation has added new and better features and higher data rates. Many older phones still work fine with 2G technology because the carriers support it (except for analog phones which disappeared in 2007). All phones are now digital radios where the voice signals are digitized, then compressed and transmitted as low speed digital data. The other applications in the phone are handled by higher speed digital circuits.

It is the modulation and access methods that determine data speeds. Most 3G phones use CDMA (code division multiple access): a modulation and access method that allows multiple users to share a single chunk of radio spectrum without interfering with one another. Qualcomm — one of the leading chip suppliers for handsets — developed the concept and patented much of it. Their technology called cdma2000 is widely used in US and Asian phones. Carriers Sprint Nextel and Verizon use this method which takes BPSK and QPSK modulation in a 1.25 MHz band that up to about 64 users can occupy simultaneously. With different modulation methods, data rates have reached well over 2 Mbps.

AT&T and T-Mobile use another form of CDMA called wideband CDMA based on a standard from the Third Generation Partnership Project (3GPP) and ITU. It uses a 5 MHz channel and QPSK modulation to achieve up to 2 Mbps of data rate. Keep in mind that while the technology defines the maximum data rate, a subscriber rarely gets it as the ultimate data rate depends on signal strength, noise, surrounding objects, and other factors. A recent enhancement to WCDMA 3G is something called high speed data access. It uses more aggressive 16QAM modulation to boost speeds to well over 10 Mbps under ideal conditions. It is now available in most new 3G smartphones.

With 4G technology, an entirely new radio method is being adopted. Called Long Term Evolution (LTE), this 4G method uses orthogonal frequency division multiplexing (OFDM). OFDM is the technique of taking the digital data stream to be transmitted and dividing it into many parallel slower data streams and using each to modulate a separate radio carrier within the used spectrum, typically 20 MHz. This technique helps improve signal reliability over longer distances and helps mitigate the effects of multiple path signals that are common at the microwave frequencies cell phones typically use. The result is higher data rates as great as 100 Mbps. LTE is still in development but the standard is expected to be finalized this year with first deployments not expected until late 2010 or 2011.

■ FIGURE 3. The Dell Mini 9 is a great example of the recent models feeding the surge in netbook interest. Small size, light weight, long battery life, and lots of wireless connectivity are its benefits.

THIRD PARTY APPLICATIONS

Another movement started by the iPhone is the Applications store. An apps store is an online place where cell phone subscribers can go and download new functions and applications. The apps are software that run on the phone's processors and create new functions and unique features.

Apple has hundreds of these now for the iPhone thanks to hundreds of independent software developers. Many apps are free but most are inexpensive enough to afford. Developers want to make money from them but manage to keep the price low thanks to high volume.

Google has an apps store for its Android phones like the HTC G1 from T-Mobile. BlackBerry and Nokia also just announced apps stores for their smartphones, and more are on the way. Your phone is a computer for the most part — except for the radio — with keyboard, touch screen, and LCD display. Why not make use of this with new software just like the PC does?

MOBILE TV

You can now actually get TV on some cell phones.(see **Figure 2**). Both AT&T and Verizon offer a selection of video programs like news, weather, sports, and a few others for a subscription fee of about $30/month. The video comes to you over the network so it is relatively slow and low res, but you can view it despite the small screen size. The trend is more toward over the air TV for cell phones where the cell phone contains a separate receiver chip that picks up broadcast TV from special stations like those set up by MediaFLO.

MediaFLO broadcasts TV in selected cities in the 700 MHz band (which will be freed up on June 12 when all analog TV goes off the air).

Soon, some US TV stations will be able to broadcast their regular programming in a new format compatible with cell phone screens. A new standard based on the US digital TV standard designated by the Advanced Television Systems Committee (ATSC) has been created. Known as ATSC M/H for

mobile/handset, it is a compatible subset of the original standard. It uses 8VSB modulation and special coding to ensure reliable TV reception in a mobile mode. Look for cell phones in the future to include their own internal receiver chip and antenna that can pick up local stations that adopt the new standard.

THE HOT NEW MOBILE DEVICE

While the smartphone is a hot item, it has to share some of the recent spotlight with the netbook. The netbook as you probably know is that smaller laptop that is taking sales away from more traditional larger laptops. It has a seven to 10 inch screen, uses Intel's new Atom processor, and uses Flash solid-state mass storage rather than a hard drive. It is considerably lighter than other notebook computers and uses either Windows XP or Linux for an OS.

It all started with the Asus Eee PC but now HP and Dell have models to compete (see **Figure 3**). These new computers will do almost as much as a regular laptop but do it cheaper. They are becoming an option to a smartphone for some people. If you do not like the small screen and cramped keyboard of the smartphone but want wireless connectivity, the netbook is the way to go.

Besides having built-in Wi-Fi to hit your favorite hot spots, many netbooks are embedding regular cellular technology so Internet access can be had through their wireless carrier. WiMAX broadband will no doubt show up on netbooks.

Carriers are beginning to offer these devices like cell phones in that they subsidize the price of the device. AT&T is now offering a netbook for $50 if you sign on for a two year data contract. Not a bad deal at all. Look for netbooks to capture a growing share of both the traditional laptop and smartphone markets. **NV**

For Dads and Grads!

We Put The FUN In Electronics!

Tri-Field Meter and "Ghost Detector"

✔ See electric, magnetic, and RF fields!
✔ Watch the magnetic fields of the earth!
✔ Sense different magnetic poles
✔ Detect RF transmitter fields
✔ Graphical LED display allows you to "see" the invisible fields

Recently seen on Ghost Whisperer!

Call it a Tri-Field Meter, an Electrical, Magnetic, and RF Detector, a Ghost Detector, or a Tricorder that even Mr. Spock would like, but what ever you call it, it works great to detect all three invisible fields!

The TFM3C has three separate field sensors that are user selectable to provide a really cool readout on two highly graphical LED bargraphs! Utilizing the latest technology, including Hall Effect sensors, you can walk around your house and actually "SEE" these fields around you! You will be amazed at what you see. How sensitive is it? Well, you can see the magnetic field of the earth... THAT'S sensitive!

The technical applications are endless. Use it to detect radiation from monitors and TV's, electrical discharges from appliances, RF emissions from unknown or hidden transmitters and RF sources, and a whole lot more! If you're wondering whether your wireless project or even your cell phone is working, you can easily check for RF! A 3-position switch in the center allows you to select electric, magnetic, or RF fields. A front panel "zero adjust" allows you to set the sensors and displays to a known clean "starting point".

If the TFM3C looks familiar, it's probably because you saw it in use on the CBS show Ghost Whisperer! It was used throughout one episode (#78, 02-27-2009) to detect the presence of ghosts! The concept is simple, it is believed (by the believers!) that ghosts give off an electric field that can be detected with the appropriate equipment. In the electric mode, the TFM3C's displays will wander away from zero even though there isn't a clear reason for it (not scientifically explainable, aka paranormal!). This would mean something has begun to give off an electric field. What it was in the Ghost Whisperer was a friendly ghost. What it will be in your house... who knows!

Makes a great teaching tool too! Learn all about the three types of fields and the sensors needed to detect them. Runs on 6VDC (4 AA batteries, not included).

TFM3C — Tri-Field Meter Kit With Case — $74.95

The High Tech Spotlight!

Hi-Res Elevation Sensor

✔ Elevation resolution to 1/3"!
✔ Pressure resolution to .0001kPa!
✔ 128x64 pixel graphical display!
✔ USB computer interface!
✔ Built-in Li-Ion battery!

The response to the UP24 was incredible! Customers from professional land surveyors, meteorologists, scientists, pilots and hikers to the curious hobbyist were overwhelmed with its sensitivity and accuracy. Reading realtime elevation to a third of an inch blew their minds! We made it even better...introducing the next generation UP24B!

First, for extended field use, we designed an internal lithium ion power cell and a state of the art power management system. Now you can charge it while it's connected to your USB connection, or use an external charger! Next we added a "MARK" feature. This allows storing a single data point reading when YOU want instead of blindly storing readings at the selected sample rate from an external switch (dry or electronic). Data is in comma delimited form for easy spreadsheet use.

Then we streamlined the controls to make a more compact profile. The rotary menu navigation dial has been replaced by contactless proximity buttons for more reliable operation! Just touch your way through the menus without any dials or switches! All in a handheld device that weighs less than 4oz! Visit www.ramseykits.com for details, there's just too much to fit here!

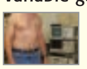
UP24B — Elevation/Pressure Sens Kit — $239.95
UP24BWT — UP24B Factory Asmb — $299.95

Signal Magnet Antenna

Super Hi-Q ferrite rod antenna with Faraday shield eliminates noise from power lines, dimmers, static and more! Great results from 500kHz to 15MHz. Super for AM broadcast band! Includes power supply.

SM100 — Signal Magnetic Antenna Kit — $89.95

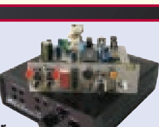
ECG Heart Monitor



Provides a visible and audible display of your heart rhythm! Variable gain, bright "beat" LED, and monitor output for display on your scope. Just like the lab! Reusable sensors are included. Req's 9V batt.

ECG1C — ECG Heart Monitor Kit — $44.95

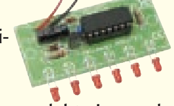
Digital Voice Storage



The *Bullshooter-II* provides up to 8 minutes of digital voice storage that can be broken down into 8 separate stored messages! Great for announcements, etc. Built-in mic plus external input. Runs on 12VDC or our AC125 PS.

BS2C — Digital Voice Storage Kit — $89.95

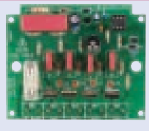
Mini LED Light Chaser



This little kit flashes six high intensity LEDs sequentially in order. Just like the K80302 to the right does with incandescent lights. Makes a great mini attention getter for signs, model trains, and even RC cars. Runs on a standard 9V battery.

MK173 — Mini LED Light Chaser Kit — $13.95

Running Light Controller



Controls and powers 4 incandescent lights so they appear to "travel" back and forth (Like the hood on KITT)! Great for the dance floor or promotional material attention getters, exhibits, or shows. Runs on 112-240VAC.

K8032 — 4-Channel Running Light Kit — $38.95

High Power LED Driver

High power LED's have finally found their way into the hobbyist budget, but now you need a driver! This little board provides the accurate and constant current need to drive them. Delivers 350mA or 700mA at a constant current

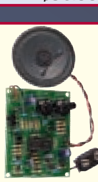
K8071 — High Power LED Driver Kit — $14.95

Digital Voice Changer

This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.

MK171 — Voice Changer Kit — $14.95

Steam Engine & Whistle



Simulates the sound of a vintage steam engine locomotive and whistle! Also provides variable "engine speed" as well as volume, and at the touch of a button the steam whistle blows! Includes speaker. Runs on a standard 9V battery.

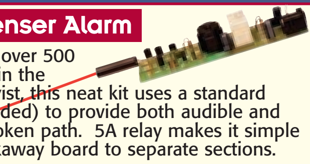
MK134 — Steam Engine & Whistle Kit — $11.95

Electronic Watch Dog

A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Even includes adjustable sensitivity! Eats 2-8VAC or 9-12VDC, it's not fussy!

K2655 — Electronic Watch Dog Kit — $39.95

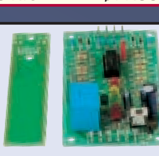
Laser Trip Senser Alarm



True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 — Laser Trip Sensor Alarm Kit — $29.95

Liquid Level Controller



Not just an alarm, but gives you a LED display of low, middle, or high levels! You can also set it to sound an alarm at the high or low condition. Provides a 2A 240VAC rated relay output. Runs on 12-14VAC or 16-18VDC.

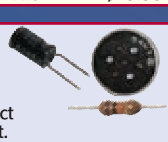
K2639 — Liquid Level Controller Kit — $23.95

Retro Nixie Tube Clock

Genuine Nixie tubes popular in the 50's brought back in one of the neatest digital clocks around today! Hand made teak maple base, 12/24 hour format, soft fade-out, auto-dim, and a crystal time base at 20ppm!

IN14TM — Teak Maple Nixie Tube Clock Kit — $329.95

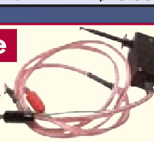
Electret Condenser Mic



This extremely sensitive 3/8" mic has a built-in FET preamplifier! It's a great replacement mic, or a perfect answer to add a mic to your project. Powered by 3-15VDC, and we even include coupling cap and a current limiting resistor! Extremely popular!

MC1 — Mini Electret Condenser Mic Kit — $3.95

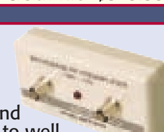
Sniff-It RF Detector Probe



Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 — Sniff-It RF Detector Probe Kit — $27.95

Broadband RF Preamp



Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.

PR2 — Broadband RF Preamp — $69.95

OBDII *CarChip Pro*

The incredible OBDII plug-in monitor that has everyone talking! Once plugged into your vehicle it monitors up to 300 hours of trip data, from speed, braking, acceleration, RPM and a whole lot more. Reads and resets your check engine light, and more!

8226 CarChip Pro OBDII Monitor $99.95

Practice Guitar Amp & DI

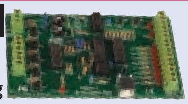
Practice your guitar without driving your family or neighbors nuts! Works with any electric, acoustic-electric, or bass guitar. Plug your MP3 player into the aux input and practice to your favorite music! Drives standard headphones and also works as a great DI!

PGA1 Personal Practice Guitar Amp Kit $64.95

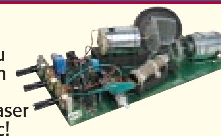
Passive Aircraft Monitor

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for air-shows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 Passive Aircraft Rcvr Kit $89.95

USB Experimenters Kit

Get hands-on experience developing USB interfaces! 5 digital inputs, 8 digital outputs, 2 analog I/O's! Includes diagnostic software and DLL for use with Windows based systems. The mystery is solved with this kit!

K8055 USB Experimenters Kit $49.95

Laser Light Show

Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 Laser Light Show Kit $49.95

Electronic Siren

Exactly duplicates the upward and downward wail of a police siren. Switch closure produces upward wail, releasing it makes it return downward. Produces a loud 5W output, and will drive any speaker! Horn speakers sound the best! Runs on 6-12VDC.

SM3 Electronic Siren Kit $7.95

Universal Timer

Build a time delay, keep something on for a preset time, provide clock pulses or provide an audio tone, all using the versatile 555 timer chip! Comes with circuit theory and a lots of application ideas and schematics to help you learn the 555 timer. 5-15VDC.

UT5 Universal Timer Kit $9.95

Voice Activated Switch

Voice activated (VOX) provides a switched output when it hears a sound. Great for a hands free PTT switch or to turn on a recorder or light! Directly switches relays or low voltage loads up to 100mA. Runs on 6-12 VDC.

VS1 Voice Switch Kit $9.95

Tone Encoder/Decoder

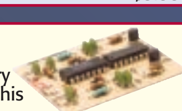
Encodes OR decodes any tone 40 Hz to 5KHz! Add a small cap and it will go as low as 10 Hz! Tunable with a precision 20 turn pot. Great for sub-audible "CTS" tone squelch encoders or decoders. Drives any low voltage load up to 100mA. Runs on 5-12 VDC.

TD1 Encoder/Decoder Kit $9.95

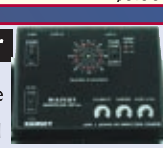
RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 RF Preamp Kit $19.95

Touch Switch

Touch on, touch off, or momentary touch hold, it's your choice with this little kit! Uses CMOS technology. Actually includes TWO totally separate touch circuits on the board! Drives any low voltage load up to 100mA. Runs on 6-12 VDC.

TS1 Touch Switch Kit $9.95

Doppler Direction Finder

Track down jammers and hidden transmitters with ease! 22.5 degree bearing indicator with adjustable damping, phase inversion, scan and more. Includes 5 piece antenna kit. Runs on 12VDC vehicle or battery power.

DDF1 Doppler Direction Finder Kit $169.95

Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

MB1 Mad Blaster Warble Alarm Kit $9.95

DTMF Encoder Decoder

Decodes standard Touch Tones from telephones, radio, or any audio source. Detects and decodes any single digit and provides a closure to ground up to 20mA. Great for remote tone control Runs on 5VDC.

TT7 DTMF Encode/Decode Kit $24.95

Super Snoop Amplifier

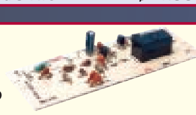
Super sensitive amplifier that will pick up a pin drop at 15 feet! Full 2 watt output drives any speaker for a great sound. Makes a great "big ear" microphone to listen to the "wildlife" both in the field and in the city! Runs on 6-15 VDC.

BN9 Super Snoop Amp Kit $9.95

Water Sensor Alarm

This little $7 kit can really "bail you out"! Simply mount the alarm where you want to detect water level problems (sump pump)! When the water touches the contacts the alarm goes off! Sensor can even be remotely located. Runs on a standard 9V battery.

MK108 Water Sensor Alarm Kit $6.95

RF Actuated Relay

Just what you need when adding a preamp or power amp in line with an antenna! Auto senses RF and closes an on-board DPDT relay that's good to UHF at 100W! Also great to protect expensive RF test equipment. Senses as low as 50mW!

RFS1 RF Actuated Relay Kit $19.95

HV Plasma Generator

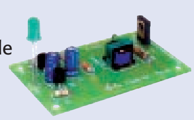
Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

PG13 HV Plasma Generator Kit $64.95

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 Ion Generator Kit $64.95

Tickle-Stick Shocker

The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 Tickle Stick Kit $12.95

Speedy Speed Radar Gun

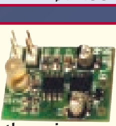
Our famous *Speedy* radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC125 supply.

SG7 Speed Radar Gun Kit $69.95

IC AM/FM Radio Lab

Learn all about AM/FM radio theory, IC theory, and end up with a high quality radio! Extensive step-by-step instructions guide you through theory, parts descriptions, and the hows and whys of IC design. Runs on a standard 9V battery.

AMFM108K AM/FM IC Radio Lab Kit $34.95

SMT Multi-Color Blinky

The ultimate blinky kit! The 8-pin microcontroller drives a very special RGB LED in 16 million color combinations! Uses PWM methods to generate any color with the micro, with switchable speed selection. SMT construction with extra parts when you lose them! 9V battery.

SBRGB1 SMT Multi-Color Blinky Kit $29.95

3-In-1 Multifunction Lab

The handiest item for your bench! Includes a RoHS compliant temp controlled soldering station, digital multimeter, and a regulated lab power supply! All in one small unit for your bench! It can't be beat!

LAB1U 3-In1 Multifunction Solder Lab $129.95

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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✔ **90 VDC Power Supply Magic**
- ✔ **EV Battery Charger**
- ✔ **Getting An A+ In Class D**

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

DC TO DC CONVERTER

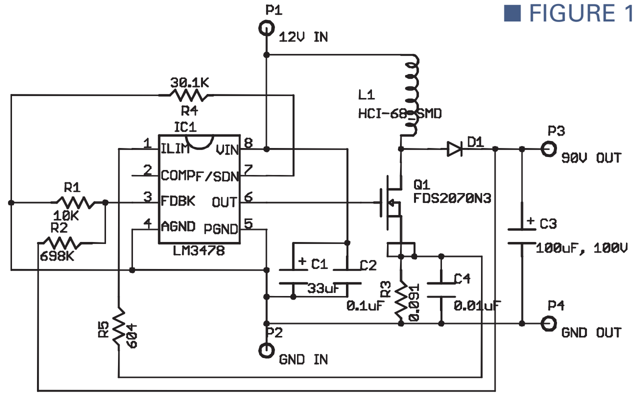
Q I have a friend in need of a power supply for his antique portable tube radio. It used the old B+ battery set that is either too expensive or no longer available.The specs are not too daunting: 9 VDC @ .5A and 90 VDC @ .1A; the 9 VDC is the easy part as I planned on substituting a small 12V gel cell with a simple nine volt regulator, but the 90 without a high part count is a little more difficult for me. So, how about a hand with a nice and simple 90 VDC at 100 mA supply that I can fit in a reasonably small package?

— Jim

A I used National Semiconductor's Webench tool to design the converter but had to change some of the parts to real world values. The schematic is in **Figure 1** and the parts list is in **Figure 2**. The LM3478 is a current mode controller. That means that current feedback from the switch transistor cuts off current through the inductor at a preset value. The amount of energy that is transferred to the output is determined by the pulse width.

In a voltage mode controller, a fixed ramp is developed by an R-C circuit; the output voltage is reduced by a divider and compared to the ramp to adjust the pulse width. In the current mode controller, the ramp is developed by the inductor current and the feedback voltage is modified by a slope compensation circuit and compared to the ramp to adjust the pulse width. It is all very complicated (which is why I use the Webench tool) but there is a good paper on the subject at: **www.national.com/appinfo/power/files/UnderstandingandApplyingCurrent-ModeControlTheoryv1.pdf**.

■ FIGURE 1



■ FIGURE 2

90 VOLT DC-DC CONVERTER PARTS LIST

PART	DESCRIPTION	SIZE	PART NUMBER	PRICE	MFR
IC1	LM3478 SIMPLE SWITCHER	8MSOP	LM3478MMTR-ND	2.62	DIGI-KEY
Q1	NMOS, 150V, 5A	DPAK	512-FQD5N15TF	0.67	MOUSER
Q1	NMOS, 150V, 4A	8SOIC-P	FDS2070N3CT-ND	1.70	DIGI-KEY
D1	150V, 2A, SCHOTTKY	SMA	497-7545-1-ND	0.56	DIGI-KEY
L1	120 µH, 2A, SMD	HCI-68	553-1420-ND	2.64	DIGI-KEY
C1	33 µF, 16V, TANTALUM	7343	399-4702-1-ND	1.60	DIGI-KEY
C2	0.1 µF, 50V, X7R CERAMIC	1206	478-1556-1-ND	1.43/10	DIGI-KEY
C4	0.01 µF, 50V, X7R CERAMIC	0805	478-1383-1-ND	0.66/10	DIGI-KEY
C3	100 µF, 100V, .18 OHMS	12.5MM	493-1977-ND	0.77	DIGI-KEY
R1	10K, 1%, 1/8W	1206	311-10.0KFCT-ND	0.88/10	DIGI-KEY
R3	0.091Ω, 1%, 1/2W	1206	P.091AUCT-ND	6.79/10	DIGI-KEY
R2	698K, 1%, 1/8W	1206	311-698KFCT-ND	0.88/10	DIGI-KEY
R4	30.1K, 1%, 1/8W	1206	311-30.1KFCT-ND	0.88/10	DIGI-KEY
R5	604 OHMS, 1%, 1/8W	1206	311-604FCT-ND	0.88/10	DIGI-KEY

Webench had an output cap of 10 µF with .001 ohms ESR; I chose an output cap of 100 µF with an ESR of 0.18 ohms. I don't know what effect that will have on the stability but the ripple voltage should be less than the 0.8 volts predicted.

The parts are all surface-mount except the output filter cap was too expensive, so I used a radial through-hole part. Soldering SMDs is not difficult if you follow this procedure: Coat the pads liberally with solder and flux; place the part and reflow the solder using a small soldering iron. You will need a 35 watt iron to reflow the drain heatsink of Q1.

4-20 mA CURRENT LOOP TEMPERATURE SENSOR

Q I am setting up a hydronic heating system for my shop and plan to control it with a micro PLC. I want to build 4-20 mA temperature transmitters for several RTDs rather than buy them. Could you offer some suggestions?

— Chuck Jensen

A I think you mean that you have a hot water heating system and want a 4-20 mA current loop sensor. I looked up an RTD and found a good one for air temperature for $85. This company also has the 4-20 mA current loop for $75. However, I don't think that is what you had in mind. I am suggesting using the LM34 Fahrenheit to voltage sensor which outputs 10 millivolts per degree F. The datasheet has a circuit for 0 deg F to 100 deg F 4-20 mA current loop. You could use that or, I designed a current loop sensor for 50 deg F to 80 deg F which I think is the range you want to control (see **Figure 3**). The parts list is in **Figure 4**.

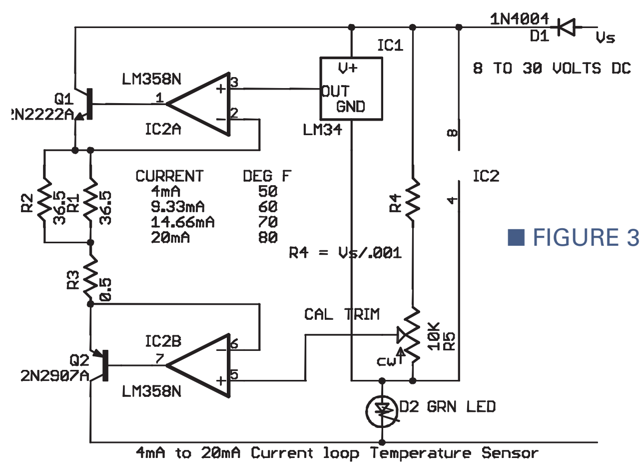
In Figure 3, the op-amp and transistor form a follower circuit where the output (at the collector of the transistor) is equal to the input. The input to IC2A is the output of IC1 which is 0.5 volts at 50 degrees F; 0.5 volts will produce 4 mA in the current loop. When the temperature is 80 degrees F, the output of U1 is 0.8 volts; we want that to produce 20 mA. The required sense resistor (R1, R2, and R3) is therefore = 0.3V/16 mA = 18.75 ohms. I used two 36.5 ohm resistors in parallel and 0.5 ohms in series because that was all I could find. I intended to get all the parts from Digi-Key (**www.digikey.com**) but could not find the resistors.

The current through R4 plus the bias current of U1 and U2 totals about 2 mA and is part of the 4 mA minimum current. The current through the sense resistor therefore must be 2 mA at 50 degrees F and is controlled by R5. R5 is adjusted until the loop current is the correct value for the temperature. The resistors R1, R2, and R3 are surface-mount so you don't have to worry about the resistance of lead wires, but keep in mind that the resistance of any PC that runs between them is part of the 18.75 ohms, so keep them short. Run the negative input of the op-amp right to the end of the sense resistor to minimize the error. The green LED is just to drop the voltage because the LM358 output can't get closer to the power rail.

■ FIGURE 4

4-20 mA CURRENT LOOP TEMPERATURE SENSOR PARTS LIST

PART	DESCRIPTION	PART NUMBER	PRICE	MFR
R1, R2	36.5Ω, 0.1%, 1/3W	66PFC12LF-36.5-B	0.70	MOUSER
R3	0.5Ω, 1%, 1/8W	66-LR2010-01-R500-F	0.55	MOUSER
R5	10K TRIMPOT	754-2668	1.12	DIGI-KEY
U1	LM34 TEMP. SENSOR	LM34DZ-ND	2.51	DIGI-KEY
U2	LM358N DUAL OP-AMP	LM358ANFS-ND	0.39	DIGI-KEY
D1	ONE AMP DIODE, 1N4004	512-1N4004	0.06	MOUSER
D2	GREEN LED, 2V	67-1052-ND	0.14	DIGI-KEY
Q1	NPN, GEN PURPOSE	512-PN2222BU	0.08	MOUSER
Q2	PNP, GEN PURPOSE	512 PN2907ABU	0.06	MOUSER

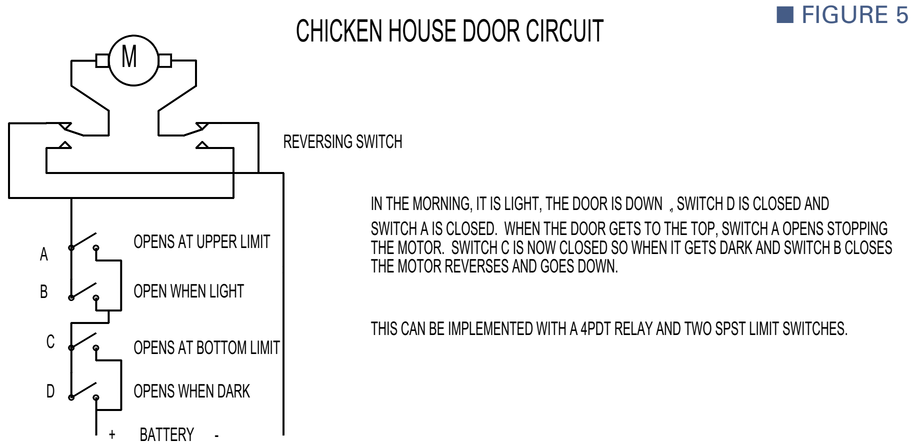


■ FIGURE 3

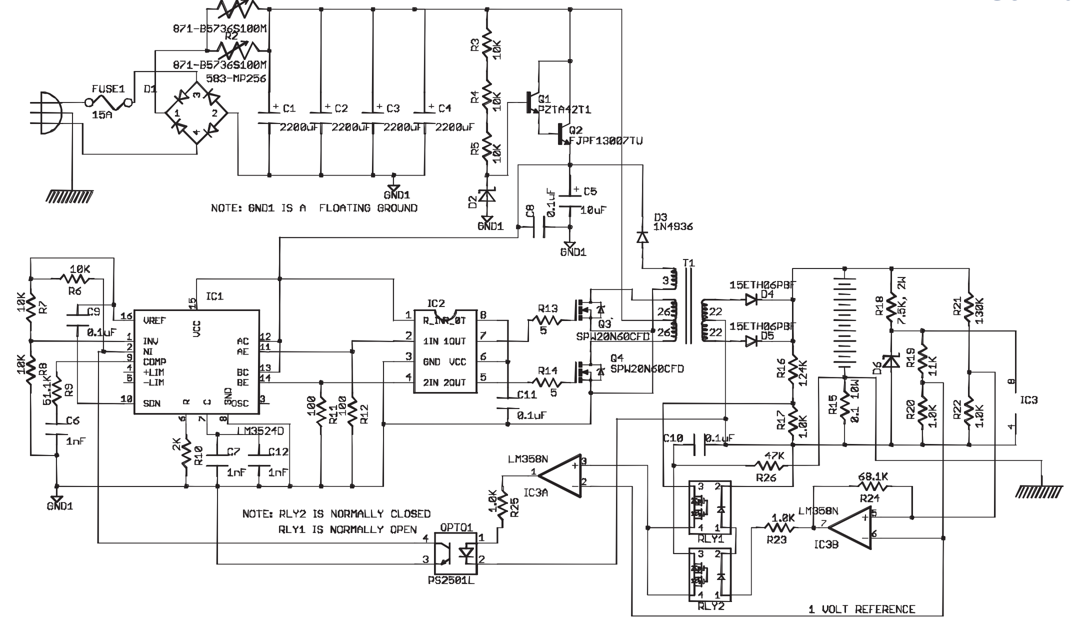
CHICKEN COOP DOOR CIRCUIT

Q I am a student from Ireland in my final year of the junior cert program in secondary school. For my technology project, I have been given the task of designing and building a chicken coop door that will open automatically at day and close at night. I have come up with the design and mechanism which will open it. I am using an LDR (light dependent resistor) which sets off a motor which, in turn, starts two pulleys which lift and close the door due to a DPDT switch. Limit switches will be used to keep the door open or closed. Would it be possible for you to show me a

■ FIGURE 5



■ FIGURE 6



suitable simple circuit design for this plan of mine in order for it to work? Your help will be gratefully appreciated.

— Christian Collins

A I don't normally do homework but this is different and I have thought about making such a circuit for my own chicken coop. The circuit and explanation is **Figure 5**. I did not show the implementation, you have to do that. Good luck with your project.

MOV TESTER

Q I am worried that my MOV equipped devices and power strips may have had their protection destroyed by a recent power hit. Some of the devices have indicator lights, but I would like to understand how they work and I would like to know if the indication is actually reliable. Please show us a safe, simple non-destructive MOV tester circuit. I have a scope available.

— George Dickenson

A An MOV (Metal Oxide Varistor) is a voltage variable resistor, somewhat like two zeners back to back but it does not have a sharp breakdown. An MOV that is designed to work on the 120 VRMS power line will start to draw current at 205 VDC and will draw its rated current at 340 VDC. All you need to test it is a 300 volt power supply and a series resistor to limit the current. I have never tested an MOV; if it is not discolored or cracked, I assume it is good. I don't know of any failure mode otherwise.

BATTERY CHARGER

Q I am looking for a low cost circuit to charge nine 12V 100 Ah AGM batteries in series or three strings of three batteries each, with each string having its own charger. This battery pack will be driving an electric conversion of a Honda Civic and I would like to be able to have the charger/s in the car and be able to plug into a standard 120 VAC 15 amp outlet. Thank you very much and I enjoy your column.

— Greg Spencer KG4UQV

A An AGM battery (Absorbed Glass Mat) is non-spillable and recombines the gases so there is never a need to add water. The charging circuit is no different from any other lead-acid battery. The float voltage is 13.8 volts, so nine of them will need 124.2 volts to maintain full charge. Since these are 100 Ah rated, the C/20 charge rate would be five amps. I think the batteries would tolerate a higher rate, however, which would allow overnight charging from full discharge. That would be C/10 or

BATTERY CHARGER PARTS LIST

■ FIGURE 7

PART	DESCRIPTION	PART NUMBER
FUSE1	PANEL MOUNT HOLDER	441-R344A-GR
D1	BRIDGE RECT. 25 AMP, 600V	844-26MB60A
D3	FAST ONE AMP, 400V DIODE	512-1N4936
R1, R2	INRUSH CURRENT LIMIT 10Ω, 5A	871-B57238S100M
C1, C2, C3, C4	2,200 µF, 250 VDC	5985-380-250V222
D4, D5	FAST DIODE, 600V, 15A	844-15ETH06PBF
D2, D6	12 VOLT ZENER, ONE WATT	512-1N4742A
Q1	NPN 300V, 500 MA	512-KSP42TA
Q2	NPN 400V, EIGHT AMP, 40 WATT	512-FJPF13007TU
Q3, Q4	NMOS, 600V, 20 AMP	726-SPW20N60CFD
IC1	PUSH-PULL CONTROLLER	511-SG3524N
IC2	FET DRIVER, TWO AMPS	595-TPS2812PE4
IC3	OP-AMP, DUAL	863-LM358DG
RLY1	NC RELAY SOLID-STATE	653-G3VM-353A
RLY2	NO RELAY SOLID-STATE	653-G3VM-351G
OPTO1	TRANSISTOR OPTO COUPLER	551-PS2501-1-A
C5	10 µF, 25V (33 µF, 25V)	647-UVR1E330MDD
C6	1,000 pF, 50V, NPO	80-C320C102J1G
C8, C9, C10, C11	0.1 µF, 50V, CERAMIC	80-C320C104K5R
C7, C12	1nF, 50V, NPO, 2%	80-C320C102G1G5TA

RESISTORS ARE 1/4 WATT UNLESS OTHERWISE NOTED
ALL PART NUMBERS ARE MOUSER (**WWW.MOUSER.COM**)

10 amps charge current.

In **Figure 6**, current feedback provides 10 amps until the battery voltage rises to 14.5 volts, then the circuit changes to a fixed voltage of 13.8 volts and remains in that mode until each battery drops to 12.6 volts. **Figure 7** is the parts list.

I want to keep the input ripple under 10 volts and since the draw is nearly 10 amps, the capacitors should have 10 amps ripple rating. Using the equation: delta V = I*delta T/C, 10 = 10*8.3ms/C, then C = 8,300 µF. Four 2,200 µF caps in parallel have more than 10 amps ripple rating. The transistors, Q1 and Q2, provide startup current to the primary circuit but after the circuit starts, the feedback from the bootstrap winding turns them off and provides the primary power. I chose a push-pull controller because that avoids DC in the transformer and allows the transformer to be smaller. The primary circuit is operating directly from the power line, so it must be enclosed such that no one can get electrocuted. The secondary is isolated and I have shown the negative terminal of the battery to be connected to the chassis.

I designed the transformer using the Magnetics, Inc., catalog for ferrite cores. Using the formula for WaAc:

$$WaAc = Po*C*10^8/(4*e*B*f*K)$$

Where:

Wa = window area in sq cm
Ac = core area in sq cm
Po = power output in watts
e = transformer efficiency
B = flux density in Gauss
f = frequency in Hz
K = winding factor

$$WaAc = 1300 \text{ watts} * 5.07*10^5 / (4*0.8*1000*10^5*.3) = 1.354$$

I chose core 44317-EC in P material. It has WaAc = 1.48 and a window area of 0.82*0.31 = .254 sq in.

Using the equation: $Np = Vp*10^8/(4*B*Ac*f)$, then $Np = 160*10^8/(4*1000*1.52*10^5) = 26$ turns, there are four windings of 26 turns plus the bootstrap winding (which I will ignore for now), so the total windings are 104. To see what wire will fit, divide the window area by 104: 0.254/104 = .0024 sq in per turn. Converting to circular mills and consulting wire tables, I find that #16 wire will fit and that should carry 10 amps with no problem. The secondary winding only needs to be 130/160 of the primary or 21 turns, but it won't hurt to use 22 turns. The bootstrap winding wants to be (15/130)*22 = 2.5 turns, so use three turns of #30 wire because it is low current.

You can try for a sample from Magnetics but if that doesn't work out, ByteMark (**www.bytemark.com**) will sell you one set of cores. Part number EA-77-625 seems to be equivalent; the window area is 0.222 sq in which is close to the 0.254 of the Magnetics core. You might have to go down one wire size to make it fit but that will not increase the temperature much.

Unless I made a math error, it should work but it has not been built, so no guarantees.

CLASS D AUDIO AMPLIFIER

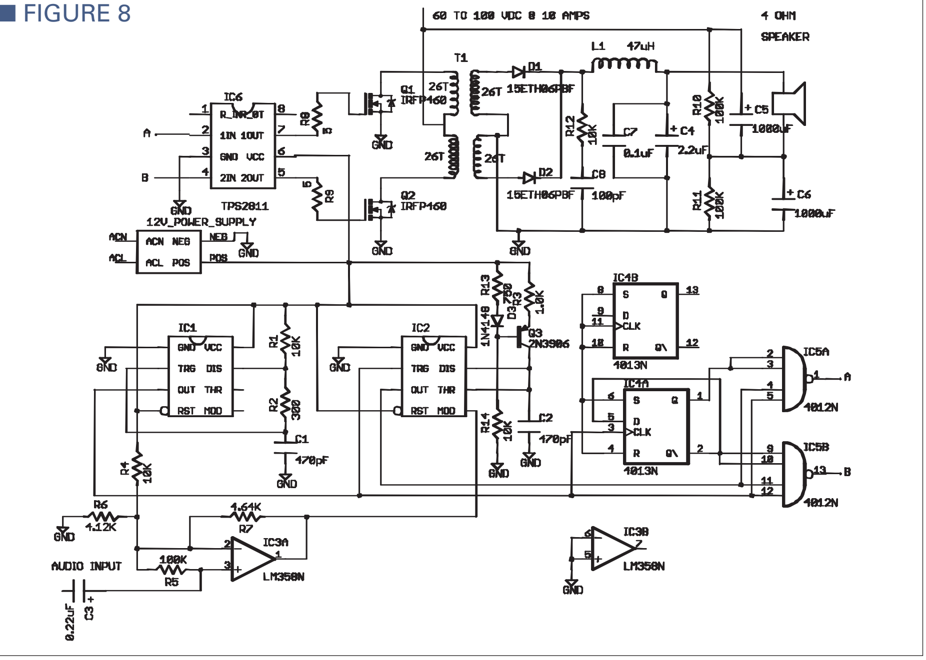
Q I have been in the industrial electronics field for over 20 years and I LOVE reading *Nuts & Volts* every month! I'm fairly impressed with the creative circuits you come up with each month. With that said, here's my question:

I have been looking for a discrete Class D audio amplifier project that uses FETs on the web for a while now but I'm not having much luck. I am looking to produce roughly 350 watts RMS of decent quality audio sound into a four ohm speaker. I was planning to double the circuit for stereo sound powered from a single bipolar power supply. I found a couple of circuits that looked pretty good but the parts were impossible to find. Do you have anything in your bag of tricks that I might be able to use???

— John Bartlett

A "Decent quality sound" is all in the ear of the beholder. I once designed and built a breadboard of a switching amplifier for a sonar project. A fellow engineer told me that the circuit would not pass the intermodulation requirements, so I did a two tone test. He was right: The sum products were only 6 dB down and nowhere near the requirements. Distortion tests for class D amplifiers are done using a single tone because a two tone test would show the distortion to be awful. It just goes to show that the human ear tolerates distortion very well (some "musicians" even add distortion!). Enough of my rant, the

■ FIGURE 8



MAILBAG

Wien Bridge Oscillator (March 2009)

Several readers, including Werner Griesshammer and Will Haas, wrote to chastise me for mis-spelling Wien. I shall try to remember "I before E except after C."

This info from reader Ron Dozier:

Now that the DTV conversion is around the corner, I'd like to impart some knowledge that I have acquired about the Digital Stream DTX9950 converter box that RadioShack sells and DTV in general.

First, **www.antennaweb.org** is so much in the news, but the information there in my opinion is not useful. **www.TVFool.com** has a lot more information. They claim you can take their Noise Margin numbers and use those as a basis to figure out what sort of antenna gain and amplification that's necessary, and thus you have a figure of merit to work with. You might be able to find that even though a station is listed in the right direction, it lacks sufficient transmitter power to be received. It also states the path of the signal and a host of other information.

www.DTV2009.gov did not show any of the options of each of the converters such as analog pass-thru which this box has.

What was unusual with the box is that if not configured, the power switch won't turn the unit off. The unit must be unplugged and plugged back in again to turn it off. The universal remote only works power, volume up, volume down, and video selector functions. People have reported that the menus are a little confusing. What I found annoying is that when you look at signal quality, the station is not listed on that screen so you can't flip through the stations and look at the quality index.

Digital Stream gave me an answer that no service manual is available when I called. I got this response by email concerning the conversion to dbm: "Thank you for contacting us. The signal is calculated by the strength that the local towers are sending." It's not signal strength, so maybe it's signal to noise in arbitrary units. It's not signal strength because when I upped the gain on my pre-amp, the quality index didn't change.

Because of the "cliff effect" or where the digital signals just disappear instead of getting weaker, I have some distribution issues to take care of, namely new antennas. What I did discover in the process — since I could not initially get channel 10 except on one TV — I had to add a tilt-compensator at the output of the distribution system. This attenuates the low frequencies. There is a higher cable loss at the higher frequencies.

Although there is a mechanism of adding channels, you have to scan them. This might prove difficult when initially pointing an antenna. I found out that if I used the remote and entered 10-1 where 10-1 was not part of the initial channel list, there was no signal. I discovered quite by accident that if I entered the corresponding UHF channel to the remote, 10-1 would be received and displayed. Therefore, these channels would best be described as "virtual channels."

One other thing is that if you read the actual transcript of the amended DTV act, it states that now expired and unredeemed coupons can be replaced subject to the household limit.

I hope this information will be useful to the readers of *N&V*.

— Ron Dozier

class D amp is in **Figure 8**.

I elected to use the classic 555 modulator circuit because I understand it and can calculate component values. IC1 is the clock which starts the ramp at IC2. The ramp and pulse stops when the charge on C2 reaches a voltage determined by the output of IC3A. Q3 is a current source so that the ramp is linear to minimize distortion. The flip-flop, IC4A, causes the pulses to be alternately fed to Q1 and Q2. That is necessary to avoid DC in the core of T1. The clock is fed to IC5 to provide dead time while the power transistors are switching. Otherwise, "shoot-thru" current would cause them to overheat. I think better power transistors could be found but the ones listed are the best Jameco has. The input capacitance is about 5,000 pF and even though the TPS2811 can drive up to two amps, the switching will be slowed.

The transformer, T1, is similar to that used in the battery charger, in fact, I would use the same core and make the primary and secondary turns equal (see the schematic in Figure 8 and the parts list in **Figure 9**).

R12 and C8 are a snubber to prevent L1 from ringing. L1, C4, and C7 are a low pass filter to keep the switching frequency and harmonics out of the speaker wires. You don't need them unless you are worried about annoying your neighbors (and yourself) with RFI. If anyone complains, the FCC could come calling.

Since this is a single ended output, a series capacitor is needed to keep DC out of the speaker. The arrangement that I used not only cuts the voltage rating of the capacitors in half, it also reduces the power supply hum.

If you are going to build two amps, I recommend that you make IC1 (the clock) common to both; that way, the switching frequencies will be the same and cross-talk problems will be minimized. I did breadboard the modulator, but the rest is "blue sky." This URL will be valuable if you intend to build it: **www.audiodesignline.com/howto/206104717**. **NV**

CLASS AUDIO AMP PARTS LIST

■ FIGURE 9

PART	DESCRIPTION	PART NUMBER	MFR
IC1, IC2	CMOS TIMER, LMC555	126797	
IC3	GEN. PURPOSE OP-AMP, LM358	120863	
IC4	CMOS DUAL FF, CD4013	12677	
IC5	CMOS DUAL 4-IN NAND, CD4012	675972	
IC6	FET DRIVER, INVERTING	735-1967	ALLIED
Q1, Q2	NMOS, 500V, 20 AMP, IRFP460	670143	
D1, D2	200V, 15A, ULTRA FAST	248-0875	ALLIED
D1, D2	200V, 30A, ULTRA FAST	787940	
D3	SMALL SIGNAL, 1N4148	36311	
L1	47 µH, 10 AMPS	542-2309-V-RC	MOUSER
C1, C2	470 pF, 5%	16109	
C3	0.22 µF, 10%, 16V	33507	
C4	2.2 µF, 10%, 150V	93999	
C5, C6	1000 µF, 10%, 100V, FIVE AMPS	598-SLPX332M 100E7P3	MOUSER
C7	0.1 µF, 10%, 150V, FILM	93921	
C8	100 pF, 5%, 150V	16002	
T1	CORE P-44317-EC		MAGNETICS
T1	CORE EA-77-625		BYTEMARK
T1	PRIMARY & SECONDARY WINDING: 26 TURNS EACH (104 TOTAL)		

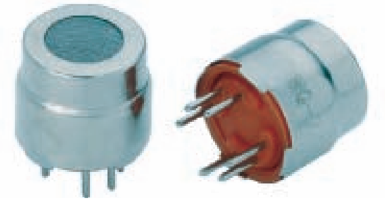
ALL RESISTORS ARE 1/4 WATT UNLESS NOTED
PART NUMBERS ARE JAMECO UNLESS NOTED (**WWW.JAMECO.COM**)

NEW PRODUCTS

- HARDWARE
- SOFTWARE
- GADGETS
- TOOLS

THREE NEW GAS SENSORS

Parallax has just released three new gas sensors. The CO Gas Sensor (605-00007) is designed for use in gas detection equipment. The MQ-7 CO Gas Sensor can be used to detect the presence of carbon monoxide in home, automotive, or industrial settings.



- High sensitivity to carbon monoxide (CO) gas
- Stable and long life
- Simple drive circuit

The CH4 Gas Sensor (605-00008) is designed for use in gas detection equipment. The MQ-2 Methane Gas Sensor can be used to detect the presence of methane in home, automotive, or industrial settings.

- Wide detecting scope
- Stable and long life
- Simple drive circuit
- Fast response and high sensitivity

The LPG Gas Sensor (605-00009) is designed for use in gas detection equipment. The MQ-5 LPG Gas Sensor can be used to detect the presence of propane in home, automotive, or industrial settings.

- High sensitivity to propane gas
- Stable and long life
- Simple drive circuit

The price is $4.99 each with quantity discounts available.

For more information, contact:
Parallax, Inc.
Web: **www.parallax.com**

ROBOT BASIC VERSION 4

Robot BASIC Version 4.0 is now available and is the biggest upgrade to date with over 300 new commands and functions. The Window's based language still lets you create and debug your programs in a fast, easy-to-use interpreter-based IDE (which has been enhanced with external editor support and improved debugging features), but now has the option of compiling stand-alone EXE applications.

This latest release has many new visual controls (now with event-handling), making it easier to create graphical user interfaces. There is also direct support for USBmicro I/O boards and a new low-level file I/O system. Internet support includes the ability to send and receive emails plus the ability to communicate with other RobotBASIC programs anywhere in the world utilizing both TCP and UDP protocols (no additional hardware needed). RobotBASIC is a very easy language to learn. To find out more about Version 4.0, visit their website and download your free copy.

For more information, contact:
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PRECISION PLIERS
BEND, CRIMP, FORM, AND HOLD SMALL ITEMS

A full line of precision pliers that are offered with 10 different head styles for use in a wide range of electronics — industrial assembly and hobby, craft, and jewelry applications — is available from Xuron Corporation.

Xuron® Precision Pliers feature specialized head styles for crimping and bending lead wires; bending and cutting applications in tight places; reaching into heavily populated PC boards; holding, bending and cutting; bending and shaping wire and thin metals; handling delicate parts; forming, looping, and shaping wire;

continued on page 64

SHOW US WHAT YOU'VE GOT!

Is your product innovative, less expensive, more functional, or just plain cool? If you have a new product that you would like us to run in our New Products section, please email a short description (300-500 words) and a photo of your product to:
newproducts@nutsvolts.com

BALLISTIC CHRONOGRAPH

If you ever wanted to know the velocity of a projectile leaving your paint gun, rifle, pistol, BB gun, slingshot, or arrow then this is a project for you. This is a great project for the marksmen or hunter that loads his own shells.

By David Collins

Last year, my son bought a chronograph. I was so intrigued by his demonstration as to how it worked, that I began to gather information from the web and finally designed my own. The info obtained pertaining to IR LEDs, IR photodiodes, LCDs, EEPROMs, and RS-232 communications were most useful in the development of this project.

FEATURES

This ballistic chronograph rivals expensive units with some *very impressive features:*

- ➤ Measures velocities (ft/sec)
- ➤ Calculates the average
- ➤ Standard deviation
- ➤ Minimum and maximum velocities
- ➤ Saves data to EEPROM and displays on an LCD

There are two velocities measured for each shot as a double check confirming the measurements. The majority of chronographs on the market today only measure one velocity. Only the very expensive ($700 to $800 range) measure two velocities. This chronograph has a maximum number of shots per series of 100 and you can record a maximum of 10 series.

The *modes of operation are:*

➤ SHOOT — measures, displays, and saves the velocities of each shot.

➤ RETRIEVE — displays the shot number, series number, the two velocities of each shot along with min, max, avg, and standard deviation for the series.

➤ SAVE TO PC — saves all the data mentioned in RETRIEVE to a file on your PC via the PC serial port; use the HyperTerminial application to receive the data and then copy it to your file (computers w/o a serial port could use a serial to USB converter).

➤ DELETE A SERIES — deletes all the data in a selected series.

➤ DELETE ALL SERIES — deletes all data in the 10 series.

All the modes are accessed via two pushbutton switches (ENTER and END) located on the front panel. In SHOOT mode, the two velocities are displayed in big numbers and readable at greater than 10 feet. The complete design is powered by a battery pack of eight AA cells. The unit will display this voltage and beep if it is less than 7.5 volts.

THEORY OF OPERATION

This project has *two major parts:*

- ➤ The three screens
- ➤ The microcontroller (µC unit)

The screens consist of photodiodes and infrared LEDs. The heart of the chronograph is the photodiode whose reverse current is proportional to the amount of incident light. Therefore, if you reverse bias the photodiode and interrupt or diminish the amount of light as seen by the photodiode, the reverse current will decrease. The momentary decrease in reverse current develops a change in voltage across R10 (**Figure 1**). This change in voltage is very small (approximately 12 mV), so the op-amps U1A and U1B (LM224) amplify it and feed it to the comparator U1C, producing a TTL level trigger pulse which is sent to the µC for timing purposes. This trigger pulse is also sent to a monostable multivibrator U1D and illuminates the green LED for about one second. *Not having a single shot digital sampling scope, I added this during the development stage in order to have visual indication of a detected pulse.*

Screen: The term screen comes from the very early chronographs where they used a metallic screen material and sensed the change in resistance as the projectile passed through. The chronographs of today are mainly optical in design.

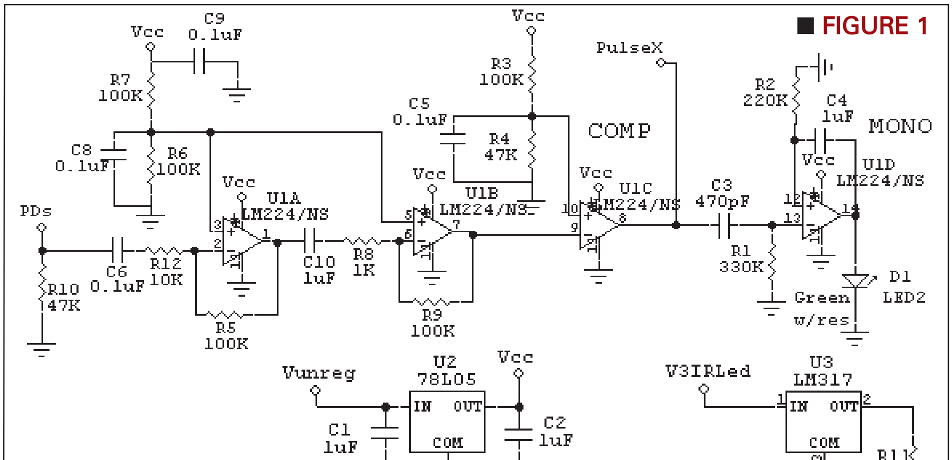
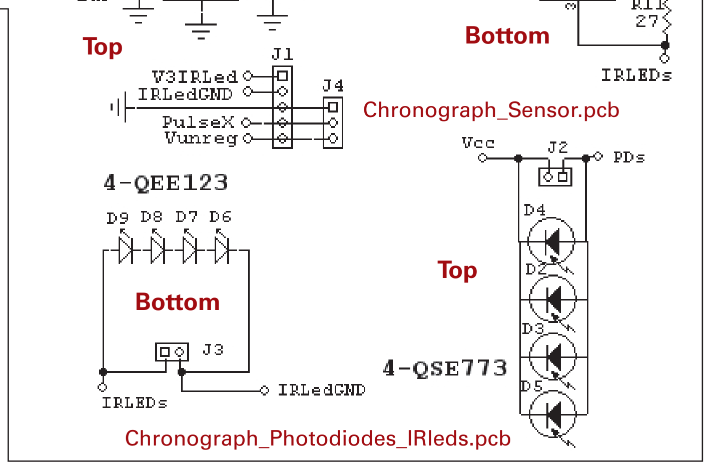
Therefore, when a projectile passes through the first screen, Pulse1 is generated which starts a timer in the µC. As it passes through the second screen (generating Pulse2), the number of timer ticks (the clock period) is saved as Ticks12. Likewise, as it passes through the third screen, Pulse3 saves the total number of timer ticks as Ticks13.

Knowing the time of each tick to be 1/Oscfreq and the distance between each screen (one foot), you can then calculate the velocities of the projectile in ft/sec as:

$$Velocity1to2 = \frac{D}{T} = \frac{1}{Ticks12 * \frac{1}{Oscfreq}} = \frac{Oscfreq}{Ticks12}$$

similarly $Velocity1to3 = \frac{2 * Oscfreq}{Ticks13}$

and $Velocity2to3 = \frac{1}{(Ticks13 - Ticks12) * \frac{1}{Oscfreq}} = \frac{Oscfreq}{(Ticks13 - Ticks12)}$

Theoretically, Velocity2to3 should be equal to or less than Velocity1to2 when the projectile has no positive horizontal acceleration. Therefore, if the two velocities do not meet these criteria, then you should be doubtful of the data. The majority of ballistic chronographs on the market rely on ambient sunlight to provide the source of illumination to the photodiodes. That's fine if you only use it outdoors on a not so cloudy day. This design is totally independent of the ambient light, relying only on the internal IRLEDs for the light source. In fact, it will operate in a totally dark environment.

The photodiodes D2-D5 used in this project are QSE773 and have peak sensitivity at a wavelength of 920 nm (infrared radiation). The IRLEDs D6-D9 used as the light source are QEE123, which has a peak emission wavelength of 950 nm. Each screen has four photodiodes flooded with four IRLEDs. A constant current generator U3 provides 46 mA to the string of IRLEDs, thus providing a constant infrared illumination of the photodiodes. This constant current is turned on/off by the µC only during the SHOOT mode thus saving a significant amount of the battery charge.

The µC U5 (**Figure 2**) performs the math operations, sends the data to the EEPROM U4, LCD U3, and/or the RS-232 drivers/receivers U1. These four ICs are powered by the five volt linear regulator U2. Note that the design also provides for a serial LCD[1] which can be connected to J7, although changes in the code would be required.

SOFTWARE

The BASCOM-AVR[2] complier version 1.11.9.2 was used to write the code (complete listing can be downloaded from **www.nutsvolts.com**) and program the µC. The current code uses about 75% of the available programmable Flash program memory so there is space remaining for your additions and/or modifications. An in-system programming connector J11 is available on the Chronograph_uC board for this purpose. **Figure 3** is the flow diagram of the present code.

All the data is stored in the 24LC65 EEPROM U4, which has a capacity of 8Kx8. These data are all defined as 16 bit words except Series_num and Shot_num and require two addresses. For that reason, one address is for the high eight bits and one for the low eight bits. The equations defining the used EEPROM addresses are:

Series_num addr = 500 + 600*(Series_num - 1) = 600*(Series_num) - 100

Shot_num addr = above+5*Shot_num - 4 = 600*(Series_num) + 5*Shot_num - 104

High(Velocity_1) = above + 1 = 600*(Series_num) + 5*Shot_num - 103

Low(Velocity_1) = above + 1 = 600*(Series_num) + 5*Shot_num - 102

High(Velocity_2) = above + 1 = 600*(Series_num) + 5*Shot_num - 101

Low(Velocity_2) = above + 1 = 600*(Series_num) + 5*Shot_num - 100

High(Velmax) = address for Series_num + 501 = 600*(Series_num) + 401

Low(Velmax) = above + 1 = 600*(Series_num) + 402
High(Velmin) = above + 1 = 600*(Series_num) + 403
Low(Velmin) = above + 1 = 600*(Series_num) + 404
High(Velavg) = above + 1 = 600*(Series_num) + 405
Low(Velavg) = above + 1 = 600*(Series_num) + 406
High(SD) = above + 1 = 600*(Series_num) + 407
Low(SD) = above + 1 = 600*(Series_num) + 408

This allocation of EEPROM memory leaves addresses 0 through 499 and 6409 through 8191 free for future data.

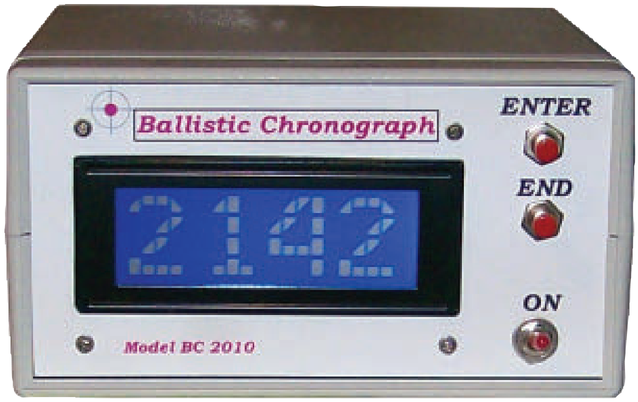
CONSTRUCTION

The design uses 13 small double-sided PCBs. The µC unit uses the Chronograph_uC PCB and each screen uses two of the Chronogrph_Sensor PCBs, along with two of the Chronograph_Photodiodes_IRleds PCBs.

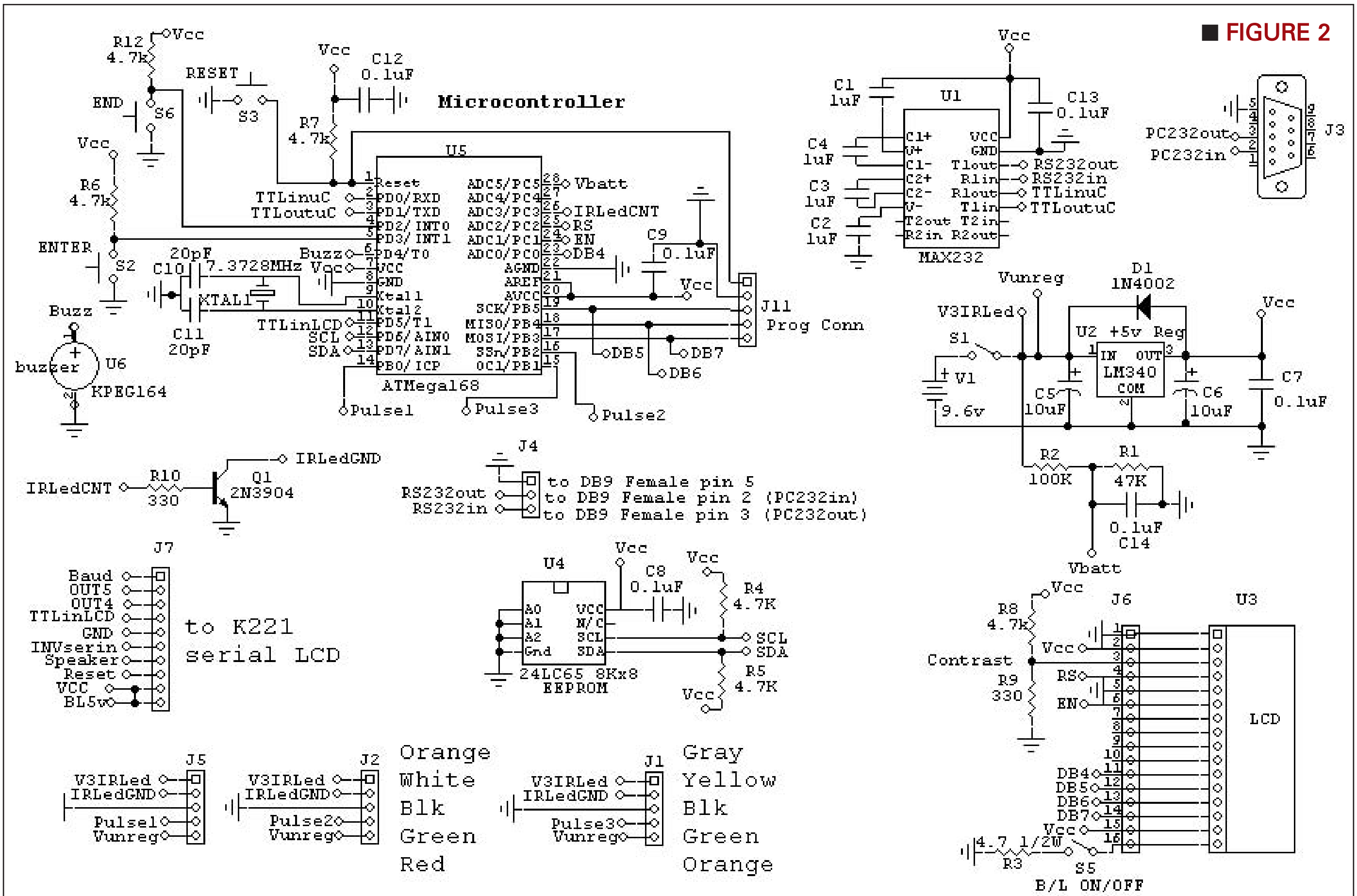
µC unit

The Chronograph_uC PCB is fairly straightforward. After soldering the components and the wires to the connectors and switches, mount the board on the back panel. I used plain faucet washers as insulators between this board and the back panel. The same was also used for mounting the LCD. The LCD is connected to the PCB using ribbon cable and IDC connectors. If needed, there is a small area on the board for future prototyping.

For the printing on the front and back panels, I used weatherproof vinyl stick-on labels[3]. Using an inkjet printer, I printed both labels, cut the openings in the panels, stuck on the labels, and then cut the openings. As a final touch, each label was then lightly sprayed with an acrylic spray[4] for added protection.



■ FIGURE 2

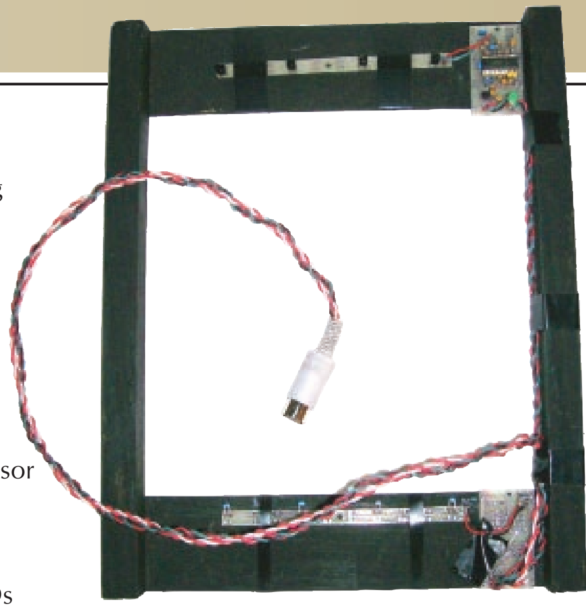


SCREENS

Each screen was made of wood with an 8" x 8" opening (shooting area) and has circuitry in both the top and bottom panels (**Figure 4**). An opening of this size should be no problem at say 10 ft. *Just don't get nervous when you shoot or you will be building another screen!* The three screens are mounted precisely one foot apart using right angle brackets on a 12" x 30" wooden board.

The top panel uses a Chronograph_Photodiodes_IRleds PCB populated with the four photodiodes D2-D5 positioned to sense the illumination from below. No wire jumpers are needed since the board puts them in parallel. This board is then wired to the Chronogrph_Sensor PCB, which is populated with U1, U2 along with the Rs and Cs. Note that this board has three wires soldered down to the bottom panel Chronograph_Sensor board. The bottom panel uses the Chronograph_Photodiodes_IRleds PCB populated with the four IRLEDs (D6-D9) and is positioned to radiate up.

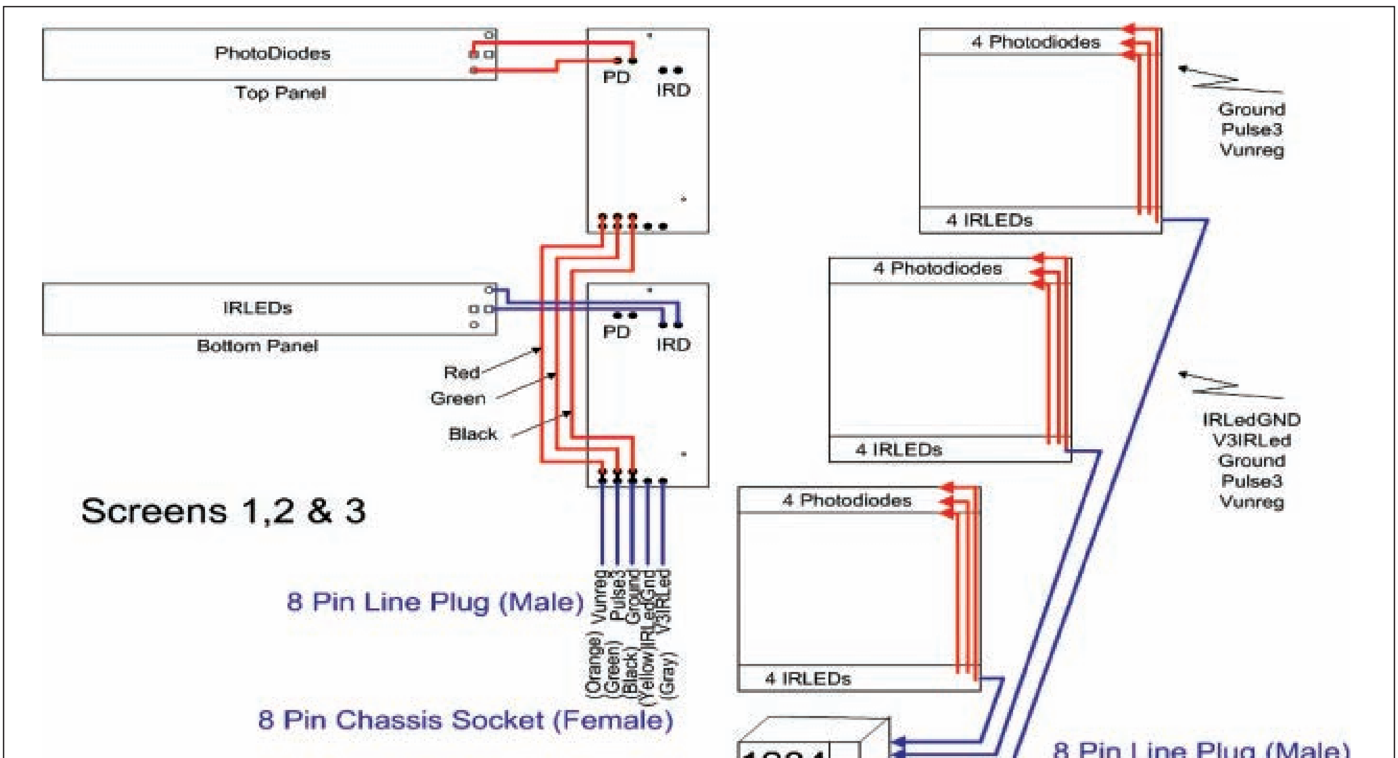
Four wire jumpers must also be soldered in to form a series string of the IRLEDs. *Originally, I designed in 10 IRLEDs and through experimentation found that four is sufficient.* This board is then wired to the Chronograph_Sensor_PCB board, which is populated with U3 and R11 and has five wires soldered to the eight pin male plugs which connect to the µC unit. **NV**



References
1 phanderson.com LCD #117 Kit
2 mcselec.com
3 onlinelabels.com #OL175WJ
4 Sherwin-Williams KRYLON Crystal Clear Acrylic Coating

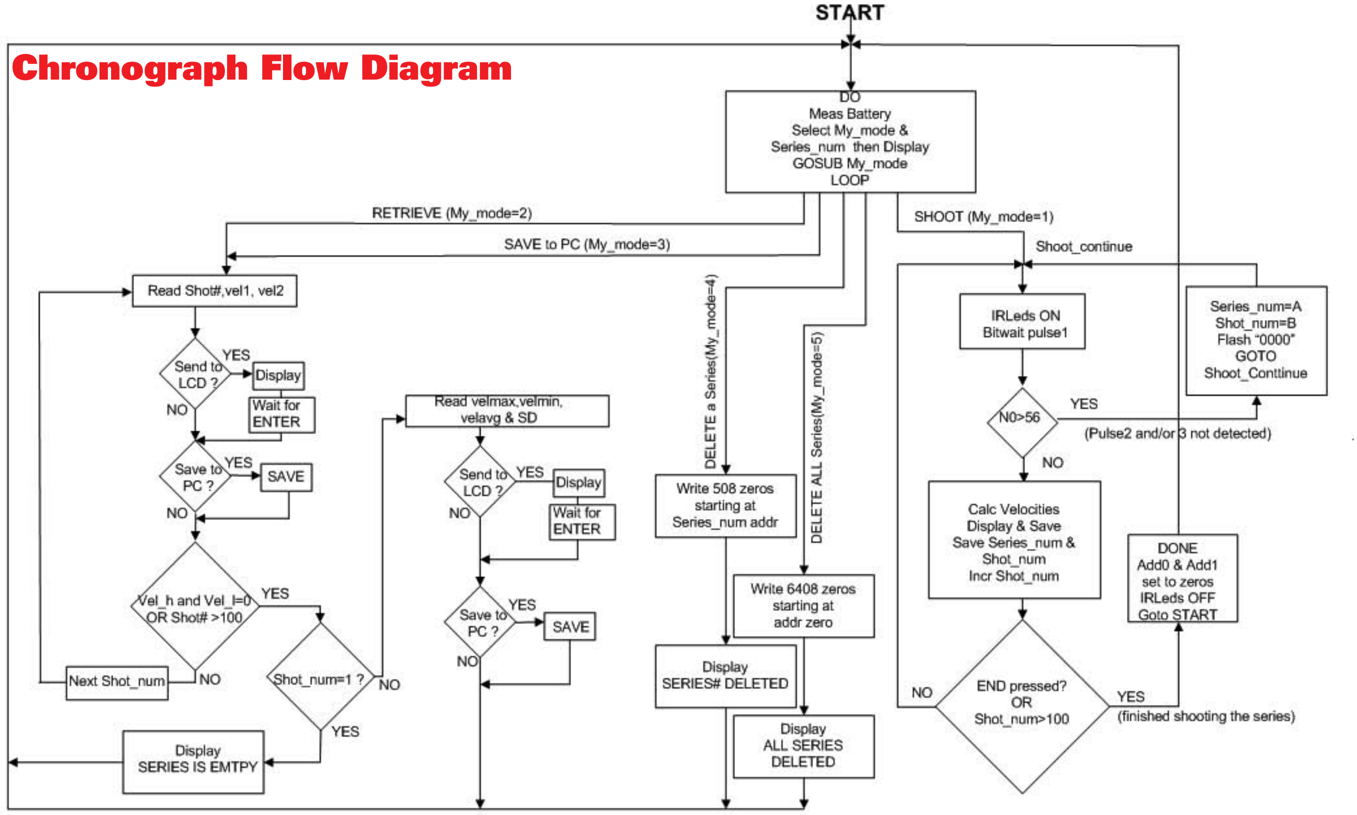
ANOTHER APPLICATION

An interesting and informative application of this chronograph is to measure the velocity of a falling object due to the earth's gravitational force. The instantaneous velocity Vi of a falling object that has traveled a distance D is given by $Vi = \sqrt{2*g*D}$ where g is the acceleration due to gravity and D is the distance traveled. So, using our chronograph with the three screens in the horizontal position and dropping say a marble from just above screen1, the displayed Velocity_1 reading should be 8.025 and the Velocity_2 reading should be 11.349. Since the present code only displays whole numbers, it should display 8 and 11, respectively. Note that in this application Velocity2to3 should be greater than Velocity1to2 since there is positive vertical accelleration (g).



■ FIGURE 4

Chronograph Flow Diagram



PARTS LIST

EACH SCREEN

TOP PANEL Chronograph_Sensor_PCB board

Qty	**Value**	**Designator**
4	1 µF	C1, C2, C4, C10
4	0.1 µF	C5, C6, C8, C9
1	470 pF	C3
1	330K	R1
1	220K	R2
5	100K	R3, R5, R6, R7, R9
2	47K	R4, R10
1	10K	R12
1	1K	R8
1	LED Green	D1
1	LM224	U1
1	78L05	U2

TOP PANEL Chronograph_Photodiodes_IRleds_PCB board

4	QSE773 Photodiodes	D2, D3, D4, D5

BOTTOM PANEL Chronograph_Sensor_PCB board

1	27Ω	R11
1	LM317	U3
3	Eight Pin Line Plug	Plugs into J1, J2, J5 (µC unit)

BOTTOM PANEL Chronograph_Photodiodes_IRleds_PCB board

4	QEE123 IRLed	D6, D7, D8, D9

µC UNIT

Chronograph_uC_PCB board

4	1 µF	C1, C2, C3, C4
2	10 µF	C5, C6
6	0.1 µF	C7, C8, C9, C12 ,C13, C14
2	20 pF	C10, C11
1	1N4002	D1
1	CONN DB9/F	J3
1	Header LCD 16 pin M	J6
1	Header LCD Serial 10 pin M	J7
1	Header Prog Conn five pin F	J11
1	2N3904	Q1
1	47K	R1
1	100K	R2
1	4.7K 1/2W	R3
6	4.7K	R4, R5, R6, R7, R8, R12
2	330	R9, R10
2	SPST Sw	S1, S5
3	Pushbutton NO	S2, S3, S6
1	MAX232	U1
1	LM340	U2
1	LCD 4x20	U3
1	24LC65 8Kx8	U4
1	ATMega168	U5
1	KPEG164	U6
1	7.3728 MHz	XTAL1
3	Eight pin chassis socket	J1, J2, J5
2	CONN 34 Contact IDC Socket	
1	Ribbon Cable 16 Wire	
1	Enclosure Hammond #1598ESGY (5.7W"x5.9L"x3.1")	
1	Battery Holder eight AA Cells	
8	Batteries AA Cells	

NOTES

All capacitors are ± 20%
All resistors are ± 5%, 1/4W unless otherwise noted

MISCELLANEOUS PARTS

Wood for each screen
- 2 pcs 3/4"x3/4"x12" (vertical pcs)
- 5 pcs 2"x1/4"x9 1/2" (horizontal pcs)
- 1 pc 3/4"x9 1/2"x30" (platform)

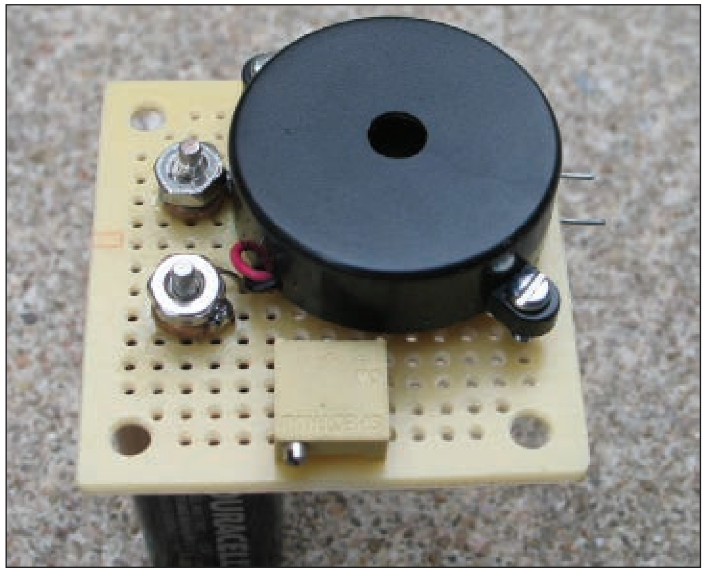
Six Right Angle Brackets
Nuts, bolts, washers, and screws

PCB gerber files and the code listing for the µC can be found in the downloads section of the *Nuts & Volts* website.
www.nutsvolts.com

ULTRA LOW POWER CMOS WATER SENSOR

My family recently moved into a two-story house with a water heater in the attic just above our bedroom. This situation made me somewhat nervous, especially after hearing stories about one of our neighbors who had returned from a vacation to find more than $10,000 worth of water damage from a leaking water heater.

They did have a drip-pan under the heater but as often happens, the drain line did not work. I don't get into my attic very often, especially in the summer. As it was, my first indication of a problem might be when water started dripping from the light fixtures. I needed a water alarm.



■ PHOTO 1. This useful device can be assembled in two hours.

By Michael Mullins

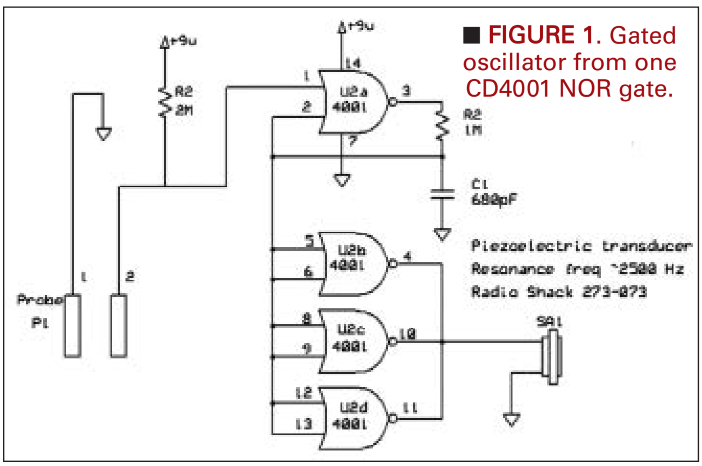
To my surprise, I was unable to locate a suitable water sensor with an alarm. ***I wanted a battery powered device that would operate unattended for at least one year.*** It needed to be inexpensive because I also wanted to place devices in other places in the attic, especially near vents where leaks might occur.

Battery operation requires careful attention to power demand. For example, a 9V battery has a typical capacity of about 600 mAh. For a 9V battery to last a year, this means the average power draw must be less than 68 µA (600 mAh, 8,760 hours/year). A power draw of 50 µA is a more reasonable target because at the end of the year there needs to be remaining power to sound the alarm.

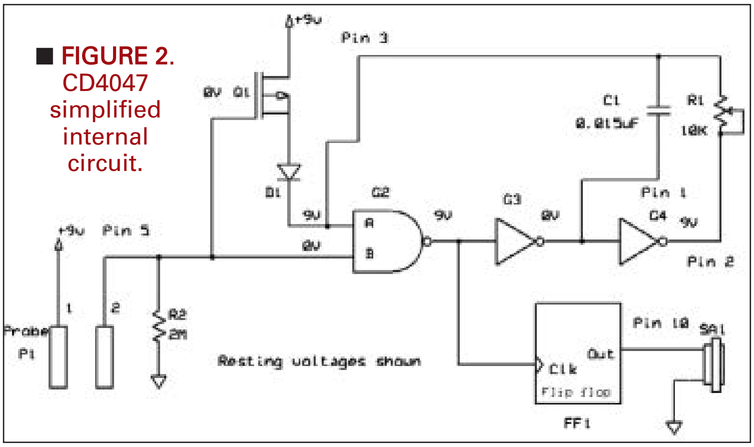
➤ ***Design #1*** — I started out with a microcontroller-based design using a float switch as a sensor. This functioned, but it did not meet my power budget. It was not difficult to lower the average power draw for the microcontroller using sleep functions and a slow clock. However, the linear voltage regulator necessary for the 5V microcontroller drew far too much quiescent current. I considered using a pair of AA batteries and using a low voltage microcontroller, but this introduced another problem. Piezoelectric buzzers generally need higher voltages for adequate sound output. It would be possible to add a step-up switcher to resolve this issue, but now the circuit was becoming complicated. For a nice example of how this can be done for a glass-breaking sensor, there is an application note from Texas Instruments using one of their low power microcontrollers (R. Kammel, K. Venkat, Texas Instruments Application Report SLAA351, Apr 2007).

Rethinking the Problem

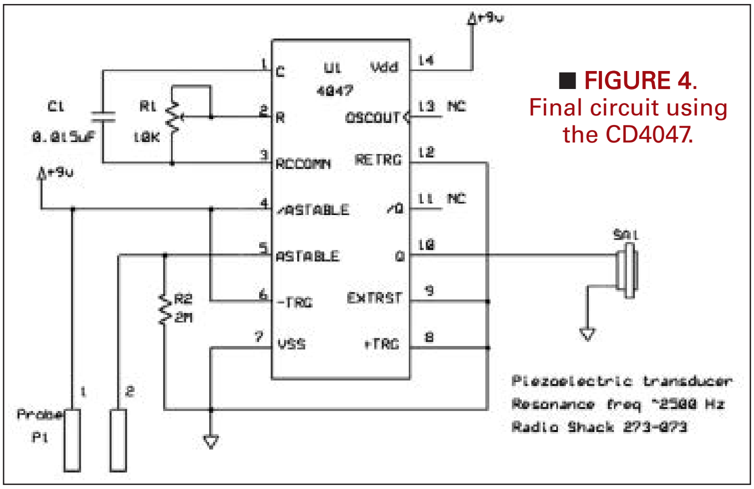
➤ ***Design #2*** — How about the old 4000 series CMOS devices I had in my junk box? They have extremely low current requirements at idle, and with their wide range of power supply voltage (3-15V), they don't need a voltage



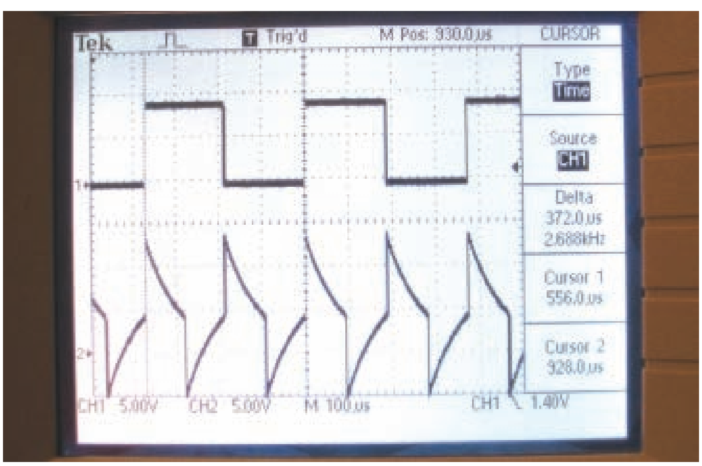
■ FIGURE 1. Gated oscillator from one CD4001 NOR gate.



■ **FIGURE 2.** CD4047 simplified internal circuit.



■ **FIGURE 4.** Final circuit using the CD4047.



■ **FIGURE 3.** Oscilloscope view of astable multivibrator in action.

regulator with a 9V battery. I started out by building a 2.5 kHz oscillator from a CD4001 NOR gate package by linearly biasing the input as shown in **Figure 1**.

The first NOR gate in this four-gate 14-pin package is used as a gated oscillator. One of the inputs (pin 2) is linearly biased by R2, and with capacitor C1, forms a 2.5 kHz oscillator. The remaining three gates are used as drivers for the piezoelectric transducer. When the probes (P1) are not in contact with water, pin 1 is high, forcing the output at pin 3 low, shutting off the oscillator. When the probes are 'shorted' by water, pin 1 is pulled low, turning on the oscillator. The extremely high (>1000 Ω) input impedance allows this simple sensor to work well.

Unfortunately, the current draw was unacceptably high (5-10 mA), even in dry conditions with the oscillator off. The culprit is the bias on pin 2 of the first gate. CMOS gates draw very little power only when the inputs are all connected to ground or Vcc.

A Better Solution

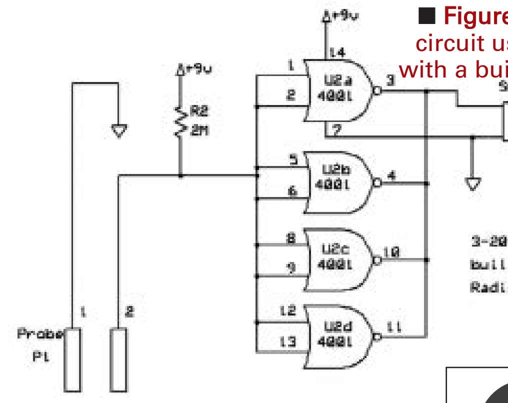
➤ ***Design #3*** — Digging deeper into my junk box, I came across a CD4047 multivibrator package that was exactly what I needed. A simplified version of the internal components of the CD4047 are shown in **Figure 2**. In the 'dry' state, NAND gate G2 has one input low and one high. The low voltage at the gate of MOSFET Q1 causes it to conduct, pulling one of the inputs to G2 (and pin 3 of the package) to be high. In this state, the device draws essentially no power. None of the internal gates are switching, and both sides of variable resistor R1 are at 9V.

When water contacts the probes, two things happen. First, one of the gates of G2 is pulled high, causing the output of G2 to go low, the output of G3 to go high, and the output of G4 to go low. Second, the gate of Q1 is also pulled high and Q1 stops conducting. Since the resting state of capacitor C1 has a 9V difference across it, when the G3 output goes high the 'top' plate is boosted to 18V. This voltage sags as R1 slowly drains the current towards 0V. When C1 drops to 4.5V, G2 switches the output to low, and the cycle continues. This package has a flip-flop (FF1) at the output of G2 that divides the frequency in half and ensures a 50% duty cycle.

A scope view of the signals at pin 10 (top trace 1, flip-flop output) and at pin 3 (bottom trace 2) is shown in **Figure 3**. The vertical scale is 5V/division, and the time scale is 100 usec/division. The numbers (1 and 2) at the left side of the scope image are at 0V of each trace. In the lower trace, the 4.5V switching point for G2 is clearly seen.

The final circuit is shown in **Figure 4**. It consists of four discrete parts, one inexpensive CMOS package, and a probe that was constructed from short pieces of heavy gauge (#6) solid copper wire. It is easy to construct on perf board. To adjust R1, the probes are shorted by touching them and R1 is adjusted for maximum sound output. I was surprised at the small current draw (3 mA) when the transducer is sounding. The volume is adequate for inside the house. This CMOS device had been patiently waiting in my junk box for 25 years, waiting for a little juice so that it could get busy.

When the probes are dry, the circuit draws less than my 2,000-count multimeter with a 200 µA scale can measure. At first, I doubted the accuracy of my meter.



■ **Figure 5.** Alternate circuit using a buzzer with a built-in oscillator.

However, a test with a 3.9M resistor (5%) and a 3.9V source, and it accurately reads 1.0 µA. **If we conservatively estimate the actual current draw is 0.5 µA, a 9V battery will last many years *(600,000 µA-hours / 0.5 µA = 136 years)*.** *Of course, the actual lifetime is actually limited by other factors, so it should be the same as the normal shelf life of the battery (~3 years).* With a fresh battery, the transducer will sound for 200 hours if a leak occurs.

A picture of the finished project is shown in **Photo 1**. The CD4047 IC is underneath the piezoelectric transducer and two short probes are shown at the right edge of the board. A 9V battery clip was attached to the bottom of the board. This device can be easily assembled in less than two hours, and the parts are readily available.

Another Option

While I was shopping at RadioShack, I noticed that they sell a buzzer with a built-in oscillator. I bought one and built the simple circuit in Figure 5. This works also, but the output volume was not quite as loud even though the power draw (10 mA) was higher. This particular buzzer was much louder at 18V, but this would require two batteries and an additional driver circuit since this voltage exceeds the limit for the power supply for these CMOS devices. The 'dry' power draw was too small to measure, as in the previous circuit.

Saved By The Buzzer

To finish the story, I built a prototype using the circuit in **Figure 4**, attached a battery, and put it next to the drip pan under the water heater. In less than two weeks, just before we were due to leave on vacation, my wife called at work ... "There's a funny noise coming from the attic." Sure enough, the water heater had begun to leak. This simple device probably saved us from a great deal of damage. In summary, microcontrollers have become amazingly powerful, but there are still times when a 25 year old integrated circuit can do a better job. **NV**

BY AL JASZEK

Turning A Microwave Oven Into A Darkroom Timer

What can you do with a dead microwave oven, a surplus wooden box, a power cord, and a socket?

Figure 1

My son is an avid amateur photographer. He had even started developing black and white negatives at home. You say, why bother with that? Well, he has a number of antique cameras, one of which is a 1917 Vest Pocket Kodak which I gave him. He even made his own roll of film for that camera. (If you want details, go to his web site, **squirrelsgolikethis.com**). *So, what does this have to do with electronics?* People who do their own developing need darkroom timers. So, he asked me to design and build one for him. I could have gone out and bought one, but there is satisfaction in doing something for yourself.

The Parts

A few years ago, our Litton microwave oven died. One of the door interlocks had failed and it would have cost too much to replace. So, I took the unit apart and saved the magnetron, the timer assembly, and the power transformer. As you might have guessed by now, I have a timer assembly that I can use for this project.

I was fortunate in that the schematic of the entire unit had been pasted into the control section of the microwave. The timer assembly was also easily removed as a unit. So, what else did I need?

The entire **Parts List** for this project included:

1. Timer assembly
2. Power cord
3. Socket
4. Case

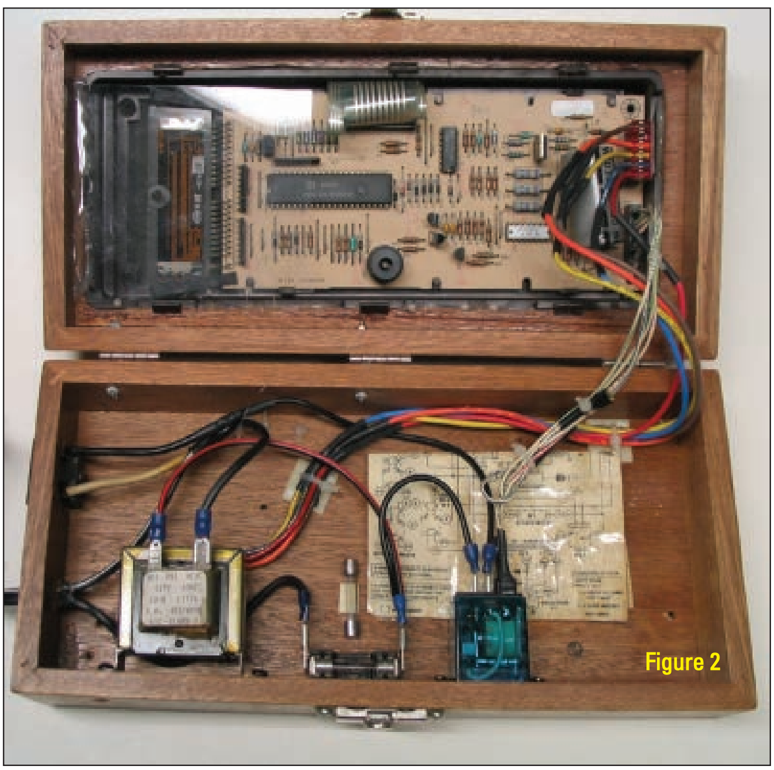
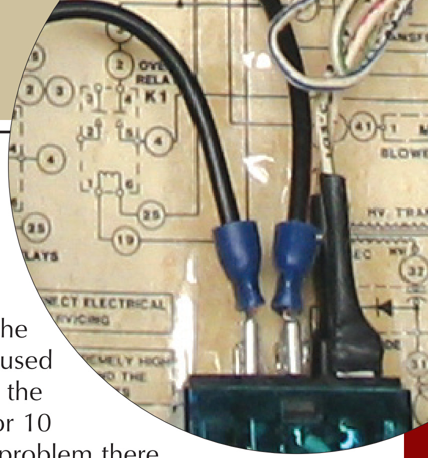


Figure 2

The wooden case I used was purchased for about $2 many years ago from a surplus store. It housed a medical device which enabled the user to transmit heart monitor information to his doctor. As pure chance would have it, it was just large enough to hold the entire timer assembly. Before I made any modifications to the case, I made sure that I would have sufficient clearance within it for all of the components. I then placed the timer assembly on the case top and traced the outline before cutting the lid to accept the timer module.

I have quite an extensive junk box. I save bits and pieces from expired appliances and electronic gadgets. I also have a great source of electronics from our town's recycling center. The electronics, the tires, the metal bits, the wood, the paper, the garbage are all collected in separate clean areas. Since our New England town does not have garbage pickup, most residents take their disposables to the town's recycling facility. People are welcome to salvage what they can.



The Timer

The timer assembly consisted of these parts:

- ➤ Circuit board mounted in the bezel
- ➤ A power transformer
- ➤ An electromechanical relay
- ➤ A solid-state relay
- ➤ A fuse block and connections for an interlock

Since I had the circuit schematic, it was an easy task to lay out and connect the components. There was a tight squeeze between the timer module and the transformer, so I had to place the transformer a distance from the module, making it necessary to lengthen the leads. There is no need for an interlock so I just shorted the interlock leads together. There was also no need for the solid-state relay, which had been used to control the magnetron, so I just bundled those in case they were needed in the future.

I drilled a hole for the power cord and also made an opening to receive a socket at one end of the wooden case. It was now a simple matter to wire the components together. I used the electromechanical relay to supply AC voltage to the socket. The timer assembly was held in place with an application of glue from a glue gun. Refer to **Figure 1** for a view of the front of the completed unit. Refer to **Figure 2** for a view of the interior. Note that the cables had to be zip tied together and anchored to the case so that there was no interference closing the lid.

Does it work? You betcha! The power level function does not work, as there is no solid-state relay. The electromechanical relay was used in the original unit to control the fan. The contacts are rated for 10 amperes so there will be no problem there. I had also replaced the original 20 ampere fuse with a three ampere fuse in the fuse block. I tested the timer by turning a desk lamp on and off.

I didn't supply the usual schematic or parts list as this project is unique. It shows what can be done with surplus or recycled components. I expect that those who have the inclination to build a darkroom timer will find materials that are significantly different from what I have used. You have to use your native intelligence. Not everything has to be thrown out and this helps our planet in a small way. And, it does the job! **NV**

What interesting things have *you* made out of recycled components pulled from electronics whose best days are behind them? Share your "recycled" creations with other readers and enter our Recycled Projects contest.
For details, go to **www.nutsvolts.com**.

A Wire-Wrapping Primer

by Vaughn D. Martin

Wire wrapping is a technique for constructing single or small numbers of simple to moderately complex electronic assemblies. It is a viable substitute to limited production printed circuit board (PCB) runs. Its most appealing characteristic is you can quickly and easily change your prototyping work. Telephone exchanges, control consoles, radar, and sonar on submarines all have successfully used this technique. Historically, the Apollo guidance computer was among many early wire wrap constructed computers. Before beginning this primer, you are encouraged to examine the sidebar glossary of wire wrapping terms.

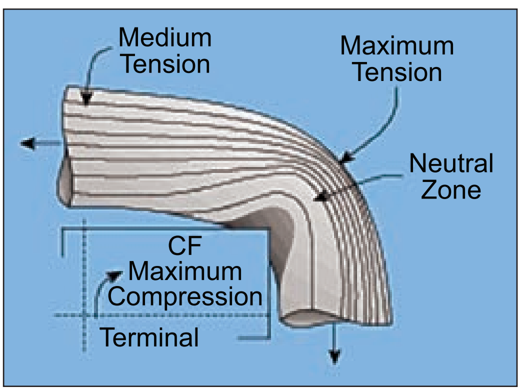
Rugged and Reliable

It may be hard to believe, but proper wire wrap construction is more reliable than printed circuits. Connections are less prone to fail due to vibration or physical stresses, as well as cold solder joints. The interior of a wire wrap connection is also air tight, and oxidation and contamination free — unlike solder that can corrode over time. Wire wrap connections are firmer and have lower electrical resistance due to actual cold welding of the wire to the terminal post at the corners.

Note: In cold welding, you apply pressure to the work pieces. Plastic deformation occurs. At least one (but preferably both) of the mating parts must be ductile (in our case, it's the wrap post).

Initial pressure at the center of the contact area can go as high as 100,000 psi. After wrapping, cold flow or cold welding causes pressure to drop to approximately 30,000 psi, then the metal stabilizes with constant pressure, completing the plastic deformation phenomenon cycle just mentioned (see **Figures 1** and **2**).

FIGURE 1. By bending the wire around the sharp corner of the terminal, the oxide layer on both wire and terminal is crushed or sheared and a clean, oxide free, metal-to-metal contact results.



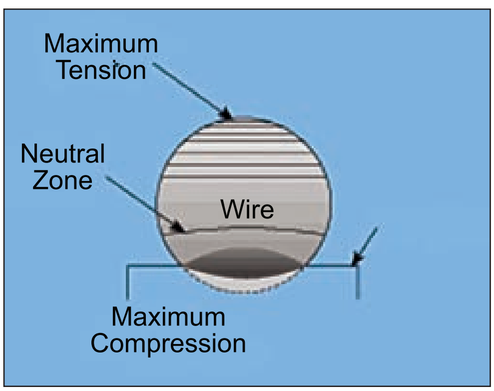


FIGURE 2. A cross section through the terminal edge shows stress distribution produced in the wire wrapped with high tension around a terminal.

Wire Wrap Posts

These moderately ductile posts are 0.025 inches (635 micrometers) square, one inch (25.4 mm) high, and spaced at 0.1 inch (2.54 mm) intervals. Premium wrap posts are a hard-drawn beryllium-copper alloy plated with 0.000025 inches (25 microinches, 635 nanometers) of gold to prevent corrosion. Less-expensive hobbyist grade posts use tin plated bronze.

Wrap Post Materials

Six commonly used materials for wrap posts are: (1) the premium beryllium copper; (2) hobbyist grade phosphor or tin plated bronze; (3) half hard brass; (4) copper nickel;

(5) nickel silver alloys; or (6) plated steel. See **Figure 3** for an example of highly dense wrap post spacing.

The Wrapping Tool

This special tool greatly varies in its level of sophistication; however, all have two holes. You insert the wire and one quarter inch (6.35 mm) of insulated wire in the tool's hole near its edge (see **Figure 4**). Then, you place the tool's center over the post. Rapidly twist the tool. The result is that 1.5 to two turns of insulated wire are wrapped around the post, and atop that, seven to nine turns of bare wire are wrapped around the post. The post has room for three such connections;

FIGURE 3. An example of high density wire wrapping.

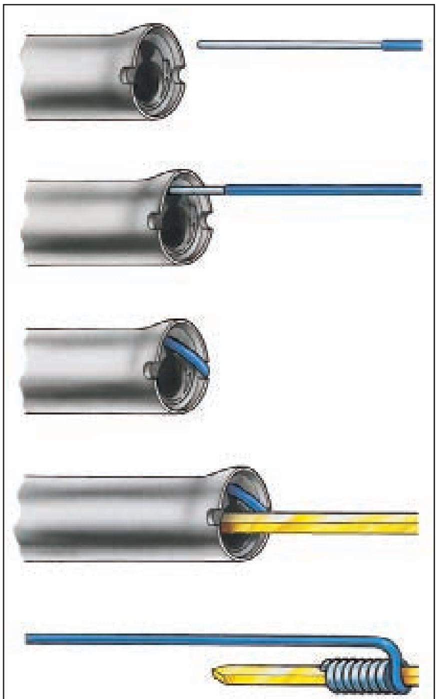


FIGURE 4. A step-by-step process of wire wrapping viewed from the tool's end.

Wire Wrapping Terms

- ***Anti-Backforce (ABF):*** A wire wrapping gun or mechanism with a spring mechanism behind the wire wrapping bit. When you pull the trigger, the bit recedes back into the wire wrapping sleeve.
- ***AWG:*** Abbreviation for American Wire Gauge.
- ***Bare Wire:*** Bare wire is the wire after you remove the insulation.
- ***Bit Radius:*** The distance from the center of the terminal hole of the wire wrap bit to the outside wall of the wire wrap sleeve.
- ***Funnel:*** The end of the wire wrapping sleeve where you insert the wire. This point of the wire wrap sleeve has been flared to make it easier for you to insert the wire.
- ***Insulated Sleeve:*** This is a wire wrapping sleeve where shrink wrap has been shrunk around the wire wrap sleeve for electrical safety.
- ***Kynar Wire:*** This is the best insulation. Other types of insulation not recommended are tefzel and teflon.
- ***Modified Wrap:*** The first 1/2 to two wraps made with insulation wrapped around the terminal post. These wraps are in addition to the recommended wraps made with bare wire.
- ***No Funnel:*** This is a wire wrapping sleeve in which the end of the sleeve has not been flared: basically, a straight tube.
- ***Notch:*** The two small half circles appearing on the sides of the wire wrap sleeve where the wire enters.
- ***Notch Depth:*** This is the depth of the notch that appears on both sides of the end of a wire wrapping sleeve.
- ***Notch Width:*** This is the width of the notch that appears on both sides of the end of a wire wrapping sleeve.
- ***Sleeve Thickness:*** This is the actual thickness of the wall of the wire wrapping sleeve.
- ***Standard Wrap:*** This is when you only use bare wire to wrap the terminal post.
- ***Terminal Diagonal:*** This is the distance between two opposite points that are the furthest apart on a terminal post.
- ***Terminal Hole Depth:*** The depth of the hole in the wire wrapping bit seen at the end of the bit.
- ***Terminal Hole Diameter:*** The diameter of the hole in a wire wrapping bit seen at the end of the bit.
- ***Terminal Post:*** This is the post around which you wrap the wire.
- ***Unique Indexing Mechanism:*** This is the mechanism within a wire wrapping gun that aligns the wire wrapping bit for high quality wraps every time.
- ***Unwrapping Direction:*** The direction you unwrap a wire wrap. This can be in a right hand or left hand direction, depending on your original wrap.
- ***Wall I.D.:*** This is the inside diameter of a wire wrapping sleeve.
- ***Wire Diameter:*** Same as wire size; refers to the actual diameter of wire with insulation.
- ***Wire Gauge:*** This term refers to the size in terms of AWG (American), SWG (British), or mm (metric version).
- ***Wire Size:*** Same as wire diameter; refers to the actual diameter of the wire with insulation.
- ***Wire Wrap Bit:*** This is a wire wrap bit consisting of a terminal hole and a wire through which you place the wire to be wrapped.
- ***Wire Wrap Sleeve:*** This consists of a straight tube that may or may not be tapered at the end.
- ***Wrap(s):*** The number of insulated or bare wire wraps going 360 degrees around a terminal post.

Wire-wrap is a registered trademark of Gardner-Denver Corporation; however, the concept and technique originated and developed during the early 1950s by Bell Telephone Laboratories.

FIGURE 5. A battery operated wire wrapping tool.

FIGURE 6. An electrically operated wire wrapping tool.

FIGURE 7. A pneumatically operated wire wrapping tool.

FIGURE 8. A manually operated wire wrapping tool.

two holes at the end of a manual wire wrap tool. Neatly wrap the posts, applying precise wrapping tension. The most crucial areas are the wire itself, the wrapping method, and the wire wrap post. The wire goes in the hole near the edge and the post is inserted into the center hole.

although usually you only need one or two. This allows you to manually repair your wire-wrapping later, if needed. **Figures 5** to **8** show a battery operated, an electrical, a pneumatic, and a manual wrapping tool that you "squeeze."

The Actual Wrapping Technique/Mechanism

Most hobbyists or students on a budget typically use an inexpensive, manual wire wrap tool (see Figure 9). There are wrapping, unwrapping, and all-in-one hand tools that strip, wrap, and unwrap in one (see **Figure 10**). There are

FIGURE 9. A simple, manual handheld wire wrapping tool.

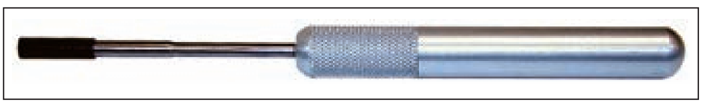
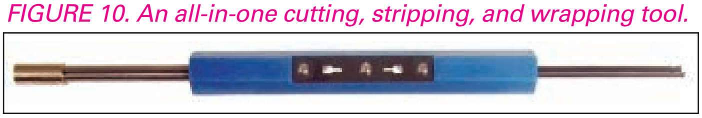


FIGURE 10. An all-in-one cutting, stripping, and wrapping tool.



Getting Started

Try to wrap one end of the wire on the lower side of a wrap post with the other end on the high end of another post. This is called the daisy-chain method (see **Figure 11**). You most appreciate this technique when you have to lift a wire off an IC pin, since using this method never requires you to remove more than one wire. If you made all the connections to a point on the bottom of the wrap post, then you would have to remove a great number of wires with resulting disorder and confusion.

The turn and a half of insulated wire helps keep the wire from fatiguing where it meets the post. Above the turn of insulated wire, the bare wire wraps around the post. The corners of the post bite in with pressures of tons per square inch, actually Mega Pascals (MPa).

Note: A Pascal is a pressure or stress equal to one Newton per square meter. A Newton, in turn, is a force producing an acceleration of one meter per second squared on a one kilogram mass.

This forces all the gases out of the area between the wire's silver plate and the post's gold or tin corners. Further, with 28 such connections (seven turns on a four-cornered post), a very reliable connection exists between the wire and the post. Furthermore, the corners of the posts are quite "sharp" — quite the opposite of being rounded off.

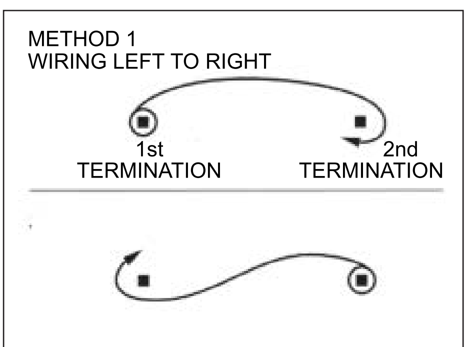


FIGURE 11a. Placing the wire in a wire wrapping tool.

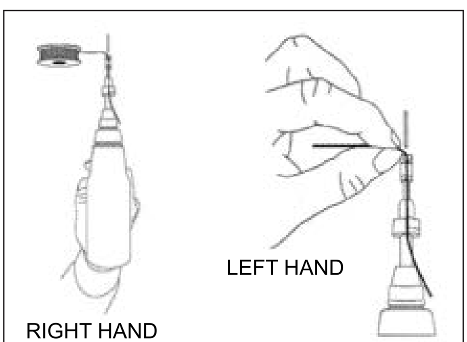


FIGURE 11b. Wrapping from post to post in a daisy-chain fashion.

Wire Wrap Wire

Wire wrap wire comes in several

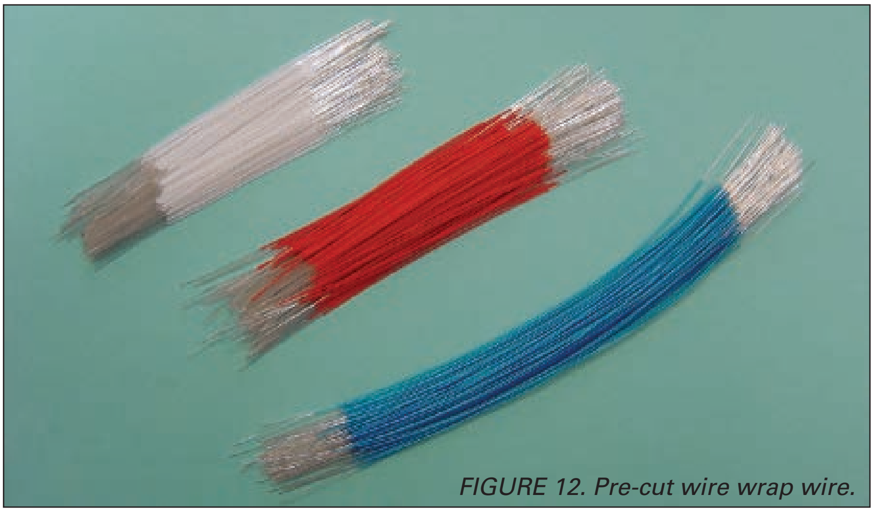


FIGURE 12. Pre-cut wire wrap wire.

FIGURE 13. Spooled wire wrap wire.

sizes (diameters). The most common insulation is “kynar,” a registered trademark of Pennwalt Corporation. This is pre-cut wire (see **Figure 12**) in various standard lengths, insulations, and colors, and also rolls (see **Figure 13**). It has one inch of stripped insulation on each end. It is an AWG 30 gauge silver-plated soft copper wire insulated with a fluorocarbon that does not emit dangerous gases when you heat it.

Discrete component holders (headers) and IC sockets with wire wrap pins are also found (see **Figure 14**). You can place these labels on the underside of an IC to help to quickly identify pins since you are looking at the IC or component from its underside. (If you suffer from spatial orientation problems or dyslexia, this is especially helpful.) Flat, interconnecting ribbon cables and other interconnecting interfacing connectors having wire wrap pin terminations are also available.

The Motivating Factors

Hobbyists have become more sophisticated and exposed to more numerous electronic products. This method allows you to repeatedly wire and rewire any circuit to change and/or experiment with (e.g., an IC’s characteristics). The use of proto boards also has its place; however, wire wrapping tends to be more permanent because of its resistance to vibration and other abuse, as previously mentioned. Also, proto boards eventually will suffer contact wear after prolonged use, whereby the contacts no longer hold the wire tightly and present an added unforeseen resistance. Proto boards can also suffer from using too large a wire that springs their contacts. Wire wrap boards will last forever if you properly care for them by not applying lateral force to the pins. You’ll break them off if you repeatedly bend them over and straighten them too many times.

In small engineering development labs or within hobbyist workshops, computer driven wire wrappers do not exist (see **Figure 15**). Usually the wrapping tool looks like a fat pencil and does wrapping on one end, unwrapping on the other, and has a slit in which to place the wire. The wire is then given a quick tug, stripping away the insulation. There is a middle ground of sophistication with electric, handheld guns that now even have bits that automatically strip away the insulation to a predetermined length. You simply press the trigger which twirls the bare wire around the post.

AWG American Wire Gauge

Hobbyist’s wrap wire is almost always 30 gauge or 30 AWG. The AWG stands for American Wire Gauge and #30 ASA has a 100.5 circular mil cross-sectional area. This determines wire resistance and its current carrying capability. A general approximation is that for each three numbers you go down in the AWG chart, you experience a doubling in cross-sectional area. So, you would expect a #27 wire to have twice the cross-sectional area of a #30

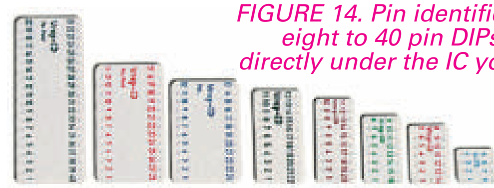


FIGURE 14. Pin identifiers from eight to 40 pin DIPs that go directly under the IC you wrap.

FIGURE 15. A sophisticated wire wrapping mechanism.

Table 1

AWG	Diameter in	Diameter mm	Minimum # of Turns Bare Wire	Minimum Strip Force lb	Minimum Strip Force gms
Wrapping Specifications for Wire					
16	0.051	1.30	4	15	6800
18	0.0403	1.02	4	15	6800
20	0.032	0.81	5	8	3600
22	0.0253	0.64	5	8	3600
24	0.0201	0.51	6	7	3200
26	0.0159	0.40	7	6	2700
28	0.0126	0.32	8	5	2200
30	0.010	0.25	8	3	1400
32	0.008	0.20	8	3	1400

TABLE 1. Wire selection table demonstrating that a minimum elongation of 15% is required for 24 through 32 AWG, while 20% is necessary for larger wire sizes.

AWG wire. Actually, it is 201.5 / 100.5 circular mils for a 2.005 ratio — which is almost exactly a doubling in cross-sectional area.

Wire Wrap Wire Insulation

As previously mentioned, there are numerous types of wire wrap insulation with kynar being the most popular with hobbyists because of its ease of stripping. The wire's insulation is no greater than the thickness of either the wire itself or any less than 80 percent of this dimension. The smaller the wire, the more it stretches. (Refer to **Table 1**.) All three popular wire wrap sizes —24, 26, and 30 — have 30,000 psi tensile strength. Wire wrap wire insulation bonding strength is crucial for automatic wrapping machinery that has to know how hard to pull to adequately strip away the insulation. The hobbyist is not too concerned about this, but kynar insulated #30 AWG requires three to 12 oz. pull to strip back one inch of wire.

FIGURE 16. A standard wrap.

FIGURE 17. A modified wrap.

Standard versus Modified Wraps

In a standard wrap, you wrap the bare wire around the post with the insulated portion being wrapped only a fraction of a revolution. You wrap the insulated portion of the wire between one and two full revolutions in the modified wrap. The modified wrap is more secure and better for smaller size wire such as #30 AWG (**Figures 16** and **17** shows the difference between a standard wrap and a modified wrap.

Wire Wrap Terminal Shapes

Let's take a look at for the wire wrap post or terminal. This piece of hardware is usually square; however, there are oblong and rectangular shaped posts (see **Figure 18**). These are less popular and effective because of the "pigtail" that typically results. A pigtail is the end of the wire that does not conform to the shape of the post, but rather has a tendency to stand out.

There are three rules of thumb with respect to wrap posts: (1) The wrap post should not be less than one wire diameter; (2) The wrap post width should not be more than 2-1/2 times the wrap post's thickness; and (3) The maximum wrap post width should not be more than three times the conductor's diameter. Also, the wrap post should be long enough to accommodate two wire wrap connections. A quick rule of thumb for determining the number of wraps is to divide the AWG number by four. Therefore, a #30 AWG wire should have approximately 7-1/2 wraps, with the first and last wraps not counting because they are not involved in the wrap's bonding.

Some Additional Tips

Examine any wrap post you are replacing for excessive damage. Critically inspect if the wrap post is starting to crack and pull away from the board. Insert the wire as far as it will go up into the bit or wrapping tool. Always dress the wire in a wrapping direction. Never try to reapply the wrapping tool

FIGURE 19. An unwrapping tool to remove a wrap.

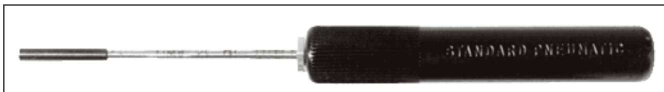
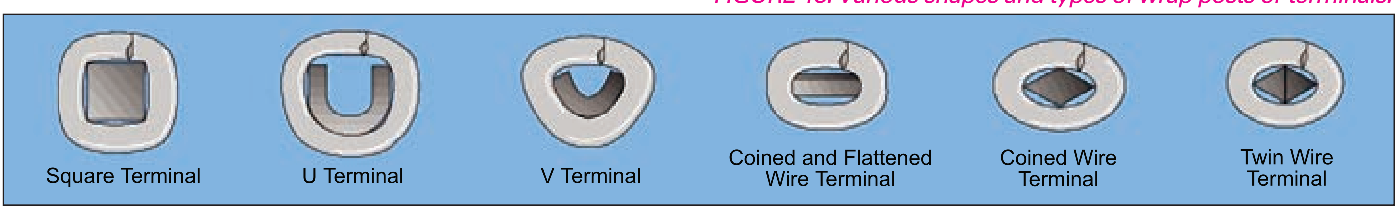


FIGURE 18. Various shapes and types of wrap posts or terminals.



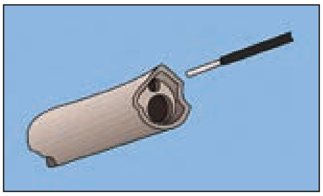


FIGURE 20a. Insert the pre-stripped wire into the wire slot of the wrapping bit.

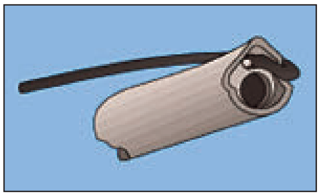


FIGURE 20b. Anchor the wire in the notch of the wrapping sleeve.

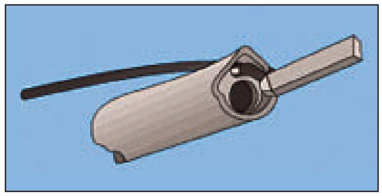


FIGURE 20c. Insert the terminal into the center hole of the wrapping bit.

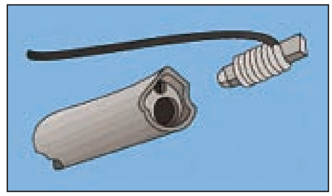


FIGURE 20d. Activate the wire wrapping tool. This rotates the wrapping bit and wraps the wire around the terminal.

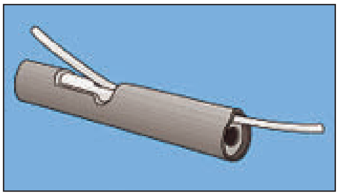


FIGURE 21a. Insert the insulated wire into the bit and sleeve.

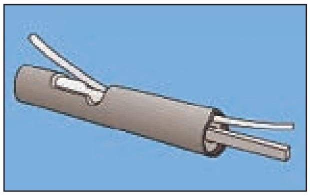


FIGURE 21b. Place the tool over the terminal to be wrapped.

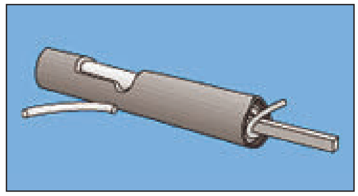


FIGURE 21c. The wire wrapping tool. Excess wire is cut off as the tool starts to wrap.

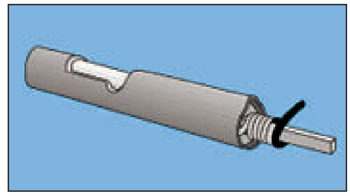


FIGURE 21d. Insulation stripping and wire wrapping are simultaneous.

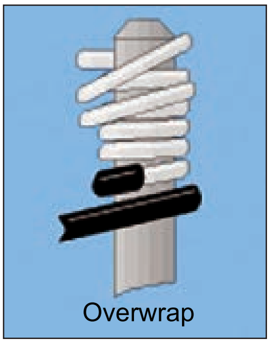


FIGURE 22a. Don't press too hard on the tool during the wire wrapping operation. This results in "overwrapping" in which one or more turns of wire can slip over the preceding turns. An anti-backforce device is helpful in preventing overwrap.

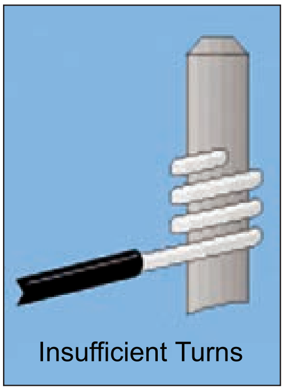


FIGURE 22b. Push the wire all the way into the wire slot. Improper feeding of the wire into the slot of the bit results in insufficient turns of wire for regular wraps or insufficient insulation turns for modified wraps.

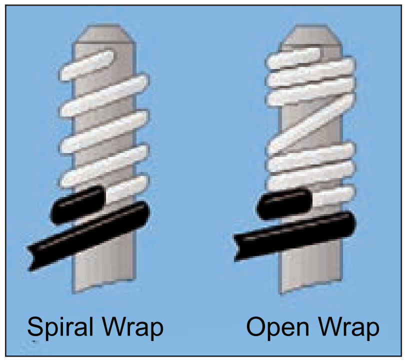


FIGURE 22c. Don't remove the tool too quickly before you complete the wrap. This results in "spiral" or "open" wraps where one turn of wire is more than 0.005" from another turn. Pigtails, are where the final turn of wire is not completely wrapped. Too rapid removal of the wrapping tool can cause this. An anti-backforce device will help reduce this problem.

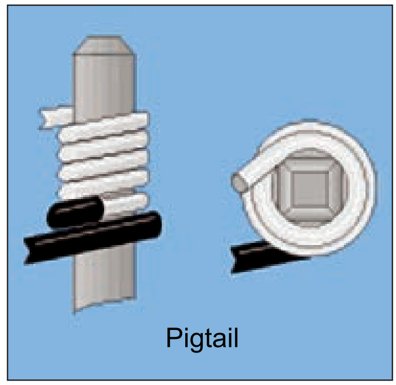


FIGURE 22d. Select the proper bit and sleeve. The particular wire wrapping bit and sleeve depend upon the size (terminal diagonal) of the terminal you are wrapping. An improperly matched terminal hole diameter or bit to the terminal diagonal causes defects ranging from loose turns to "pigtails."

to a connection that you have poorly wrapped. Unwrap it and start again! Never use pliers of any kind on a wrap post. Use an unwrapping tool (see **Figure 19**). Do not use the bit and sleeve of the wrapping tool as a pry. If possible, avoid placing more than two wrap connections on a single post.

Proper Technique

Figure 20 shows the four steps in a standard mechanical wrap connection. **Figure 21** shows the four steps in a cut, strip, and wrap connection. If you follow these procedures, you will avoid four common problems (see **Figure 22**). And, that's a wrap! **NV**

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• **www.standardpneumatic.com/resource/tech_wire.html.** JDV Products Inc.'s Standard Pneumatic & Electronic Tool Company — wire wrapping tutorial

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#11 SMILEY'S WORKSHOP

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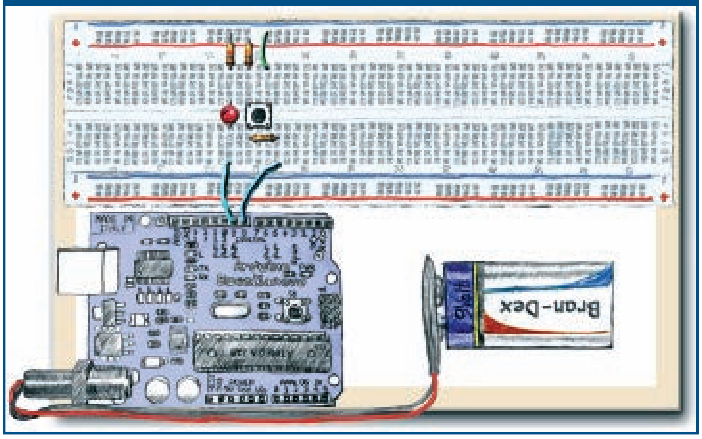


Introduction to Breadboards

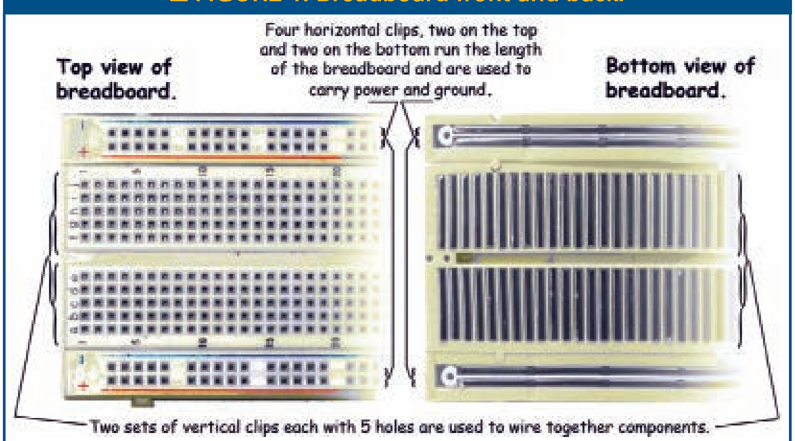
I tend to write this stuff with the idea that the reader already knows a bit about electronics. But that isn't always a valid assumption. For instance, some folks have never used a solderless breadboard. I tried to remember the first time I used one and it just seems like I was born knowing how these things work. I do have vague recollections, however, of using an ohmmeter to figure out that the + and – power busses run horizontally the entire length of the board and that the two grids in the middle of the board have vertical five-position clips. If you have already used one of these things, then skip over this section.

How a Breadboard Works

In the good old days, electronics experimenters would build prototypes by nailing components to an actual wooden breadboard and then soldering wire between connection points. Today's solderless breadboards are made of plastic blocks with holes on 0.1 inch centers that allow you to insert jumper wires (usually 22 AWG) into hidden clips below the holes. The vertical 'terminal' blocks let you connect up to five points on each of the 63 double sets of columns. These columns are separated by a 0.4 inch gutter over which you can place an IC or DIP package. You also have four horizontal power bus rows with 50 point clips on each ... Oh, who am I kidding? There is no way you can really understand what is going on by reading a written description. It is even hard to take decent photos and have it be clear what I'm talking about. So, I decided to take some photos and get out the crayons and draw some pretty pictures that might just make things clearer.

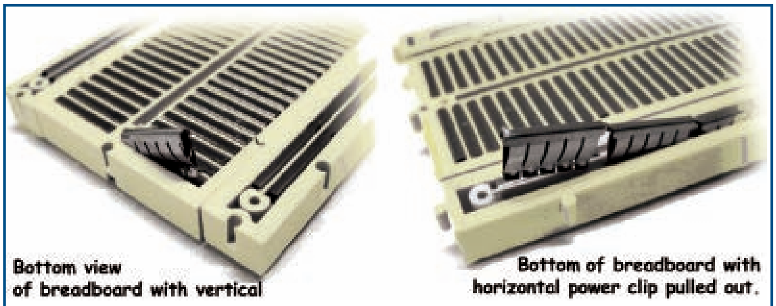
Figure 1 shows the top and bottom of a solderless breadboard (the bottom has the foam tape stripped off to show the connections. **Figure 2** shows the clips pulled out. **Figure 3** shows how a clip grabs a wire and **Figure 4** shows a cutaway drawing with an LED, 1K resistor, and a jumper wire all connected such that if you have +5 volts in the upper + channel and GND in the lower – channel, the LED should light up.

■ FIGURE 1. Breadboard front and back.



The clips should handle about one amp at five volts. Breadboards only work for relatively low frequency devices (10 MHz or less) due to high and variable stray capacitance and inductance. Also, the jumpers don't always maintain a solid connection. I can't count the times that I've had a circuit go weird until I jiggled a few wires and the weirdness went away. However, I've gotten micro-controllers to work with 16 MHz external clocks on breadboards, but it isn't something that you can be totally confident in so caution is advised. You are trading off reliability for flexibility (and

price). You will sometimes see an Arduino design with the ATmega and associated circuits on a breadboard, and there is nothing really wrong with doing that. Just remember, every jumper tie point adds another possible place for a bug, so you have to ask yourself if your time is worth the hassle when you can get the Arduino on a PCB (printed circuit board) pretty cheap.



■ FIGURE 2. Back with five-position vertical and 50-position clips.

An Introduction to Schematics

We usually design the schematics for our circuits using software on a PC such as the one I used to generate our schematics: EAGLE (Easily Applicable Graphical Layout Editor). It has a free version for non-commercial use (**www.cadsoft.de**). EAGLE is hard to use, as are all other schematic/layout programs I've used. If you want to use any of these programs, be prepared for a long learning curve. **Figure 5** shows a drawing and the schematic for the LED circuit.

Schematic Symbols

Schematic symbols are not standardized, but you often see symbols similar to the ones shown in Figure 5. A resistor is usually shown in America with a ziz-zag, but in Europe they may use a rectangle. The LED symbol is also the symbol for a diode but with a couple of arrows added to show light coming out. We will see other symbols as we build more circuits with the Arduino Projects Kit components.

Using a Solderless Breadboard with the Arduino

Figure 6 shows the schematic symbol for the Arduino pin-out along with the drawing of the Arduino that shows the female headers associated with the pin numbers. These headers have clips in them similar to those on a breadboard, except that there is only one clip per hole.

Schematic and Drawing for the LED and Pushbutton Projects

We saw a photo of this in Smiley's Workshop #10, but the concepts are repeated here in **Figures 7 and 8** for the circuit schematic and drawing.

Moving from TAW Serial to ACW Serial

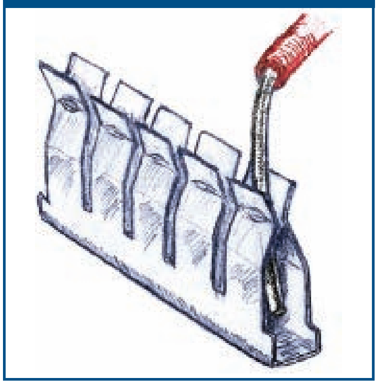
Now that you know more than you ever wanted to know about breadboards, let's move on to a new software library that will ease our porting software from TAW (The Arduino Way) to ACW (A C Way). In the last Workshop, we learned how to port the code by simply copying all the Arduino source code into our project directory. This month, we will dump all that code into a library — libACW001 — with the major exception that we will be replacing the Arduino serial functions with our own versions. Some of this will be redundant with things we saw last month, but since this can get tricky, a little reinforcement can't hurt.

Replacing TAW Serial Functions with ACW Equivalents

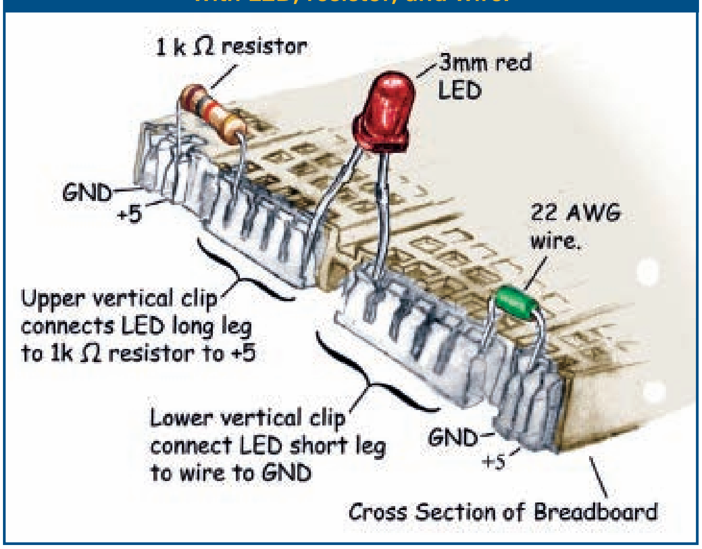
Much of the Arduino source code (as provided on the Arduino website) will be directly portable to AVRStudio using libACW001.a and the methods described in Workshops 9 and 10. Unfortunately, the serial communication function is not as simple to port, so in this section we will learn to replace them with some similar functions.

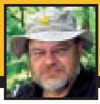
The TAW serial functions are written in C++ and we don't want to go there, so we have replaced each with an equivalent ACW function with a more C friendly name (the dot ['.'] in the middle of the C++ names gives

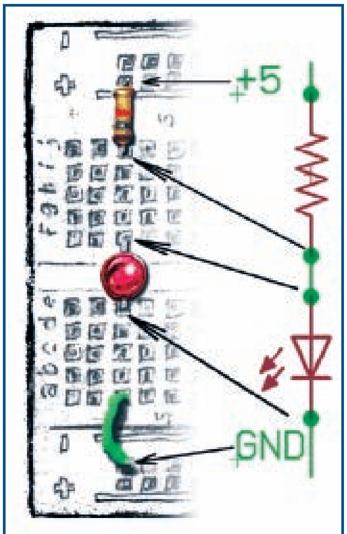
■ FIGURE 3. A five-position clip.



■ FIGURE 4. Breadboard cross-section with LED, resistor, and wire.







■ FIGURE 5. Layout drawing and EAGLE Schematic for LED.

problems that we don't need at this point). It is a relatively simple matter to redo these serial functions and we get the added advantage of using the venerable printf() standard C library function. In the old days, the first C program you'd write would use the statement printf("Hello world!"), and we'll do the same thing here, just for nostalgia's sake.

serialBegin(long speed) Replaces Serial.begin (speed)

We use this in the setup() function to set the serial port baud rate. I recommend keeping it set to 57600 which is the same as the bootloader, however, some of the examples run at 9600 baud, so be alert. The various baud rates in different source code cause no end of confusion, so again be alert. If you start receiving junk characters, you probably have the baud rate set wrong.

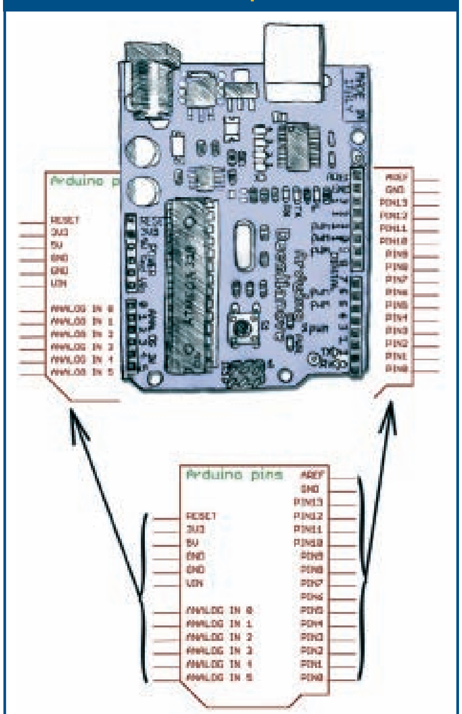
int serialAvailable() Replaces Serial.available()

This function returns the number of bytes available in the serial port buffer that holds up to 128 bytes.

int serialRead() Replaces Serial.read()

This function returns the next available byte or -1 if the buffer is empty.

■ FIGURE 6. Arduino pin-out schematic.



serialFlush() Replaces Serial.flush

This function clears the serial buffer.

printf(data) Replaces Serial.print(data) and Serial.println (data)

Now we get into some fun. The TAW Serial.print(data) and Serial.println(data) functions will mostly figure out whatever you put in 'data' and then send it out. The Serial.println() will add the linefeed character '\n' typically used to tell a terminal that the line has ended. Instead, we will use the standard C library printf() function that is not actually 'standard' in our case since it is implemented on an AVR and has some limits that are discussed in the avrlibc manual. We will get into details on this delightful function in later Workshops.

The Venerable "Hello World!" Program

In Kernighan and Ritchie's classic book *The C Programming Language* (a.k.a., K&R), the first program you write is:

```
#include <stdio.h>

main()
{
    printf(“hello, world\n”);
}
```

The code that makes the printf() function work is stored in the stdio library referenced by stdio.h. Our TAW version of this program is a bit longer than the K&R, while the ACW version is more like the original. Oh, and I changed 'hello, world\n' to 'Hello, World!\n" just because I'm more excitable than K&R. Also, we will blink an LED and repeat the process once a second (much more excitable). We don't have to do any ALP hardware setup for this since the Arduino board already has pin 13 connected to LED L.

"Hello World!" in TAW

```
// Hello World! TAW
// Joe Pardue 4-28-2009
// This program outputs
// some text and blinks
// the LED on pin 13
int ledPin = 13;

void setup()
{
  // initialize the UART baud rate
  Serial.begin(57600);

  // sets the digital pin as output
  pinMode(ledPin, OUTPUT);
}

void loop()
{
  // prints Hello World! with ending line break
  Serial.println(“Hello World!”);

  // sets the LED on
  digitalWrite(ledPin, HIGH);
  delay(1000); // waits for a second

  // sets the LED off
  digitalWrite(ledPin, LOW);
  delay(1000); // waits for a second
}
```

One last time, let's show all the details in cookbook style:

- Plug your ALPs into your PC serial port.
- Open the Arduino IDE.
- From the menu, select File\New.
- From the menu, select Tools\Boards\Arduino w/ ATmega328.
- Also in the Tools menus, select Serial Port and make sure the correct one is selected.
- Type the Hello, World! TAW version program into the sketch window. (The code is also available in the Workshop11.zip on the *Nuts & Volts* website at **www.nutsvolts.com**).
- Click the Verify button.
- Click the 'Upload to I/O Board' button.
- Watch the Tx and Rx LEDs twiddle.

Using a PC Terminal to See the Results

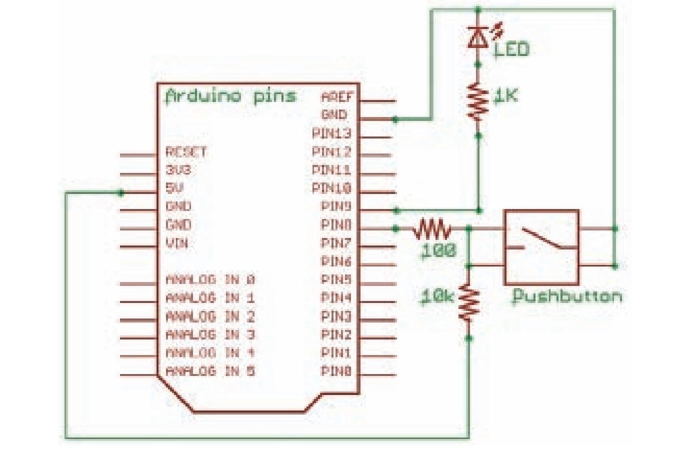
You can get the Developer's Terminal or Bray's Terminal from **www.smileymicros.com**, but any terminal program should work. We will use my terminal; instructions on how to use it are on my website. Make sure you have chosen the correct terminal and that you have set the baud rate to 57600. You can now watch LED L (pin 13) blink once per second and **Figure 10** shows the terminal output.

"Hello World!" in ACW

```
// Hello World! - ACW
// Joe Pardue March 28, 2009
// This program outputs the venerable
// first C program of "Hello, World!!!",
// then pulses the LED.

#include "libACW001.h"

// LED connected to digital pin 13
int ledPin = 13;

int main(void)
{
       init();
       setup();
       for (;;)
              loop();

       return 0;
}

void setup()
{
  // initialize the UART baud rate
  //Serial.begin(57600);
  serialBegin(57600);

  // sets the digital pin as output
  pinMode(ledPin, OUTPUT);
}

void loop()
```

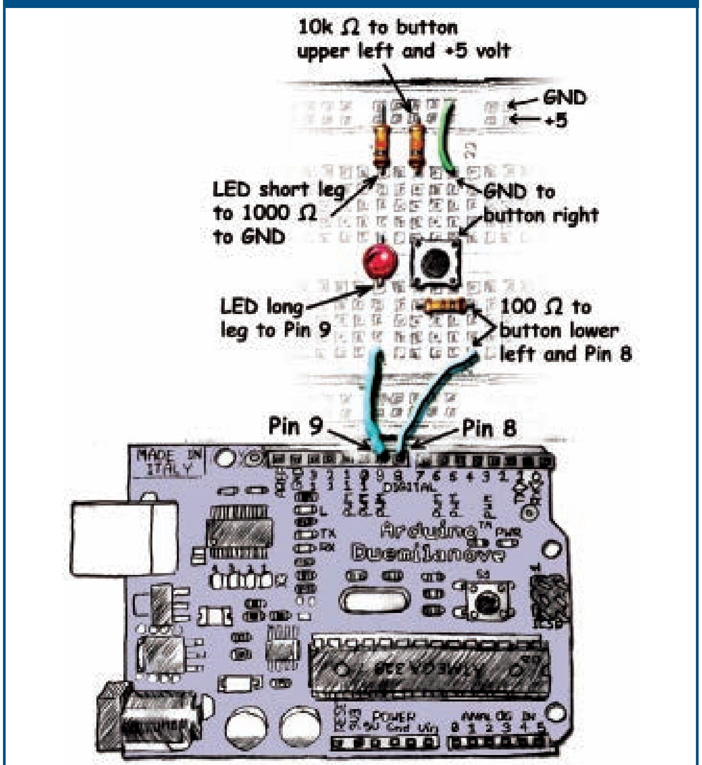
■ FIGURE 9. TAW and ACW equivalent serial functions.

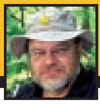
TAW	ACW
Serial.begin(speed)	serialBegin(long speed)
int Serial.available()	int serialAvailable()
int Serial.read()	int serialRead()
Serial.flush()	serialFlush()
Serial.print(data)	printf(data)
Serial.println(data)	printf(data)



■ FIGURE 7. LED and pushbutton schematic.

■ FIGURE 8. LED and pushbutton layout drawing.





Joe Pardue can be reached at **www.smileymicros.com**

```
{
  // prints Hello World! with ending line break
  //Serial.println("Hello World!");
  printf("Hello World!!!\n");

  // sets the LED on
  digitalWrite(ledPin, HIGH);
  delay(1000); // waits for a second

  // sets the LED off
  digitalWrite(ledPin, LOW);
  delay(1000); // waits for a second
}
```

This time, we will not copy the Arduino files; we will use libACW001 (libACW001.a and libACW001.h are in the Workshop11.zip). Using libraries was discussed in Workshop 4.

Now let's do it again in ACW cookbook style:

- Create a new directory C:\ArduinoToAVRStudio - Hello World!
- Open AVRStudio and create a new project 'Hello World' in C:\ArduinoToAVRStudio-Hello World. Creating AVRStudio projects is described in Workshop 2. Be sure and select the ATmega328p.
- Add the libACW001.a library and libACW001.h header to the AVRStudio project (adding libraries was discussed in Workshop 4.)
- Type in the above 'Hello, World!' in ACW source code.
- We use three exclamation points so that we can tell we've uploaded this version – the TAW version shows "Hello, World!"; the ACW version shows "Hello, World!!!"
- The AVRStudio project is available in the Workshop11.zip file.
- Click the AVRStudio compile button.

Upload It with AVRDude

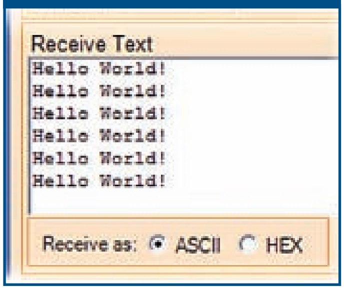
- Reread the directions for using AVRDude in Workshop 10 on how to open AVRDude and navigate to the correct directory.
- Open Notepad and type:

```
cd \ArduinoToAVRStudio – Hello World\default
avrdude -p m328p -c avrisp -P com6 -b 57600 -F
-U flash:w:HelloWorld.hex
```

- Copy and paste the first line into the cmd window and hit enter to point it to the correct directory.
- Copy and paste the second line into the cmd window.
- Push the reset button on the Arduino and at the same time click the enter button so that the cmd window will run AVRDude.
- Open the port in your terminal and you should see 'Hello World!!!" with all three exclamation points repeating once per second.

Well that should get you started and yield a base for your next weekend project. I am always curious to see what readers construct with the knowledge offered here, so if you build something nifty please drop me a note and share! My website is at **http://www.smileymicros.com/** and I always welcome your feedback, too. **NV**

■ FIGURE 10. Hello World!



You can find the source code and supplements for this article in Workshop11.zip on the *Nuts & Volts* and Smiley Micros websites.

Our Arduino Uses the ATmega328

Our Arduino Projects Kits has caused a little confusion because it uses the Duemilanove (Italian for 2009) with the ATmega328 (double the memory at the same price) instead of the older ATmega168. These processors have 32 or 16 kilobytes of memory, respectively, so they require a different setting in the Arduino IDE. For our board, open the Tools/Boards menu and select the Arduino w/ ATmega328. Also note that the bootloader runs at 57600 baud, which is faster than the older Arduino bootloader and seems to be confusing some folks on the Arduino forum, so be careful.

The Arduino Projects Kit

Smiley Micros and Nuts & Volts are selling a special kit: The Arduino Projects Kit providing components for use with Smiley's Workshops 9, 10, 11, and many future Workshops. Over time, we will learn simple ways to use these components, and more importantly we will use them to drill down into the deeper concepts of C programming, AVR microcontroller architecture, and embedded systems principles.

With the components in this kit you can:

- Blink eight LEDs (Cylon Eyes).
- Read a pushbutton and eight-bit DIP switch.
- Sense voltage, light, and temperature.
- Make music on a piezo element.
- Sense edges and gray levels.
- Optically isolate voltages.
- Fade an LED with PWM.
- Control motor speed.
- And more ...

One final note: The USB serial port on the Arduino uses the FTDI FT232R chip that was discussed in detail in the article "The Serial Port is Dead, Long Live the Serial Port' by yours truly in the June 2008 issue of *Nuts & Volts*. You can also get the book "Virtual Serial Programming Cookbook" (also by yours truly) and an associated projects kit from either *Nuts & Volts* or Smiley Micros.

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With our popular Servo Erector Set you can easily build and control the robot of your dreams. Our interchangeable aluminum brackets make the ultimate precision mechanical assemblies. Our Visual Sequencer for SSC-32 provides powerful PC, Atom, or BS2 based control.
Visit our huge website to see our complete line of aluminum and Lexan based robot kits, electronics, and mechanical components.
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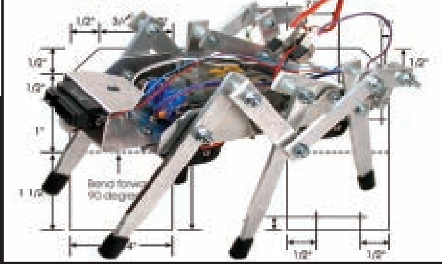
The SES now has 143 unique components!



■ BY VERN GRANER

DAS BLINKENBOARD

"ACHTUNG! ALLES NONTEKNISCHEN LOOKENPEEPERS! DAS KOMPUTEN-DEVICE IST NICHT FÜR GEFINGERPOKEN UND MITTENGRABEN! IST EASY SCHNAPPEN SPRINGENWERKEN, BLOWENFUSEN UND POPPENCORKEN MIT SPITZENSPARKSEN! IST NICHT FÜR BETOUCHIN BEI DUMMKOPFEN. DER RUBBERNECKEN TURISTEN KEEPEN DAS COTTONPICKEN HÄNDEZEN IN DER POCKETS, RELAXEN UND WATSCHEN DER BLINKENLICHTEN!"

COMPUTER ON THE BLINK?

Ah, the inevitable blinking lights. In the early days of computing, the control panels of building-sized computers bristled with literally hundreds of switches and thousands of individual light bulbs (**Figure 1**). These rows and columns of indicators not only reflected what was happening inside these giant beasts, but they also provided data and diagnostic information to the operators.

From the public's perspective, "Das BlinkenLights" were synonymous with high technology. Control panels with indicator bulbs began to make appearances in science fiction movies such as "Destination Moon" in 1950 and then migrated to robots in the 1956 classic film "Forbidden Planet" where the seven foot tall "Robby the Robot" enthralled audiences worldwide. When computers finally shrank to a size (and price) that electronic hobbyists could handle, they brought their blinking lights with them.

In January of 1975, anyone who bought a MITS Altair 8800 found it had rows of indicator LEDs for outputs and mini toggle switches for input (**Figure 2**). The wide-spread adoption of CRTs coupled with exponential increases in computer bus speeds led to a vast reduction in the need for front panel lights. It wasn't long before many computers relegated the role of LEDs to simply showing power state or disk drive activity. However, the public's perception that "blinking lights = high tech" persisted.

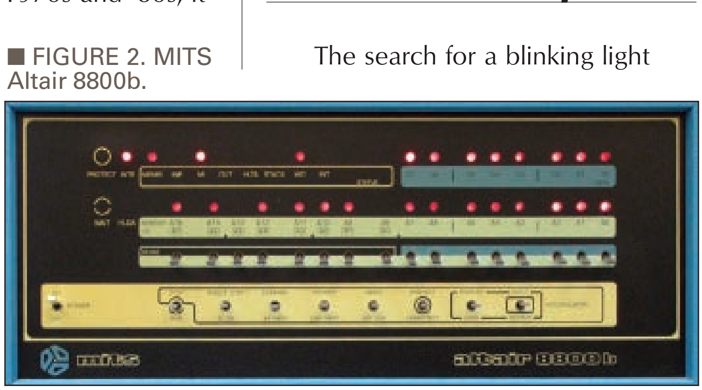
Through the 1970s and '80s, it seemed many science fiction shows just couldn't get enough blinking lights. The Robot (a.k.a., "B9") of "Lost in Space" fame had both blinking lights in his brain-bubble and pulsating pushbuttons on his chest. The chrome-plated Cylons of "Battlestar Galactica" sported spiffy sequential sweeping red-lit "eyes." Even R2D2 had multi-colored twinkling dome lights to accompany his beeps and boops.

Though recent movie robots tend to look more human, when it comes time in the plot to declare their robotic heritage, they usually pry open a panel and show off a handful of LEDs as proof of true technological nature. So, if both the public at large and Hollywood persist in believing that all things high-tech should blink, then who are we to argue?

■ FIGURE 1. IBM System/360 Model 91 at NASA in the late 1960s.

YABB (YET ANOTHER BLINKIN' BOARD)

The search for a blinking light



■ FIGURE 2. MITS Altair 8800b.

circuit was prompted when one of our regular Robot Group members, Marvin Niebuhr (a.k.a., "Professor Conrad"), expressed an interest in having a small circuit to blink lights in some of his bio-mechanical robotic art creations (see **Resources**). Though some members suggested that he could write some code for a microcontroller and just add some LEDs, he made it clear that he was more interested in building his sculptures than writing code and really preferred something simple ... something "turn-key."

As we are a rather helpful group of folks, many members started researching blinking light circuits from all over and many designs were discovered, suggested, and debated. Some circuits had LEDs lit by a decade counter chip driven by a 555 timer. Others used various combinations of dedicated logic chips to reach a similar end result. Newer designs used different microcontrollers to drive LEDs directly.

As we sought a "perfect" board, we kept coming up with features that were missing from the existing offerings or ideas on how the boards could be made more versatile and robust. These discussions brought about to a rather detailed definition of what would make a perfect board. One thing led to another and pretty soon James Delaney, Paul Atkinson, and I decided we should build a board that had all these features.

ON-BOARD VOLTAGE REGULATOR

Since a board can have either four AA batteries, a 9V cell, a 12V wall-wart, or 24 volts worth of gel cells for power, on-board regulation would allow it to be used in any power situation it might encounter in any of our existing robotic art pieces.

Being prepared for any type of power source would also make the device less likely to be damaged by improper power levels and would allow the board to be used by folks more interested in creating their robotic artwork than reading schematics and sourcing specific voltage power supplies.

A SMALL, BUT POWERFUL, INEXPENSIVE MICROPROCESSOR

After considering various processors, it was decided that the Atmel ATtiny84 was the "just right" chip for this specific job. Smaller than the "overkill" Atmega8 in its massive 28-pin package yet larger than the somewhat cramped ATtiny45 with only eight pins (two of which are already allocated to power and ground!), the best of both worlds seemed to be the ATtiny84. It has enough pins to allow us to dedicate three to use for jumper settings while still leaving eight to use as outputs. In addition, if we're careful in how we allocate pins, we could even program the chip in-circuit! With 8K bytes of Flash memory, 512 bytes of on-chip programmable EEPROM, and 512 bytes of internal SRAM, the ATtiny84 packs a heck of a punch for a very low price.

LOW-SIDE BUFFERED SWITCHING

By using the robust ULN2803A Darlington driver chip to buffer the output of the microcontroller, we get multiple benefits. First, we up the number and type of devices we can drive. Since the ULN2803 can sink up to 500 mA per channel, it is capable of driving much heavier loads than the unbuffered output of the microprocessor itself. It's possible to power strings of LEDs and even incandescent lights. Also, the 2803 has built-in "snubber" diodes that protect against back EMF so the device can directly drive inductive loads such as relays, solenoids, and motors. Being a low side driver, it can be used to drive different voltage devices from different channels. For example, you could have a six volt light bulb on channel 1, a 12 volt motor on channel 2, a three volt sound module on channel 3, and a 24 volt solenoid on channel 4.

The trick is that since the chip is only switching the device to GND, the source voltage may be different for each channel. Lastly, it acts as a "sacrificial" part. If you short the output, you may lose the device itself, but the microcontroller is usually protected from damage.

RELIABLE "ON THE FLY" PROGRAM SELECTION

Rather than a hard-coded pattern determined by logic chips or a push-button switch that would have to be set after every power cycle, we wanted a simple and robust method to choose sequences. By using regular .100" jumpers, we can select a pattern and the unit will "awaken" with that pattern every time. Also, the pins can be connected to switches instead of jumpers to allow the

LIGHTING PATTERNS

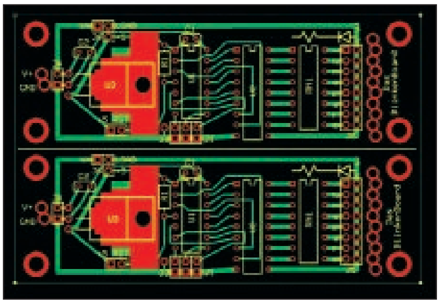
Use the following table to determine what jumpers to pick to create specific patterns.

J1-J2-J3

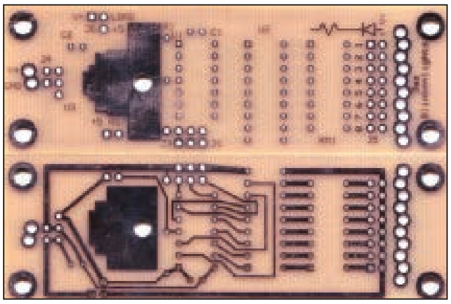
000 = Random Patterns
001 = Flame Simulator
010 = Bounce
011 = Fade Bounce
100 = Thunderbird Turn Indicators
101 = Star Twinkle
110 = Fade Chase
111 = Binary Style Counter

RESOURCES

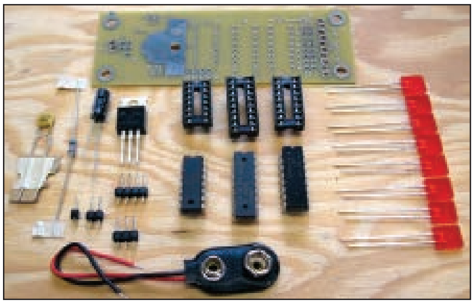
- "Blinkenlights" Neologism: **http://en.wikipedia.org/wiki/Blinkenlights**
- Marvin Niebuhr (a.k.a., "Professor Conrad"): **www.professorconrad.com/**
- James Delany's Original LED sequencer: **www.unfocusedbrain.com/projects/2009/profc**
- The Robot Group: **www.TheRobotGroup.org**
- Atmel ATtiny84: **www.atmel.com**
- Video of Das BlinkenBoard in action: **www.youtube.com/VernGraner**



■ FIGURE 3. Das BlinkenBoard “two up” layout in ExpressPCB.



■ FIGURE 4. Das BlinkenBoards from ExpressPCBs, “Miniboard” service.



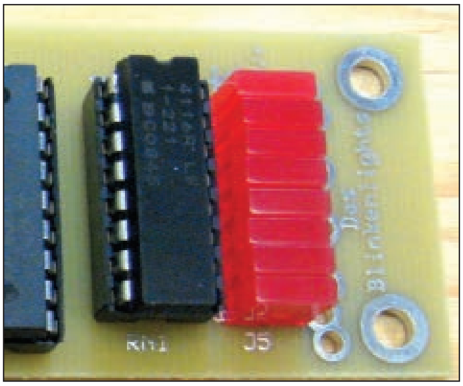
■ FIGURE 5. Das BlinkenBoard kit of parts.

sequence to be altered even after the board has been powered up.

NO ONE TRICK PONIES!

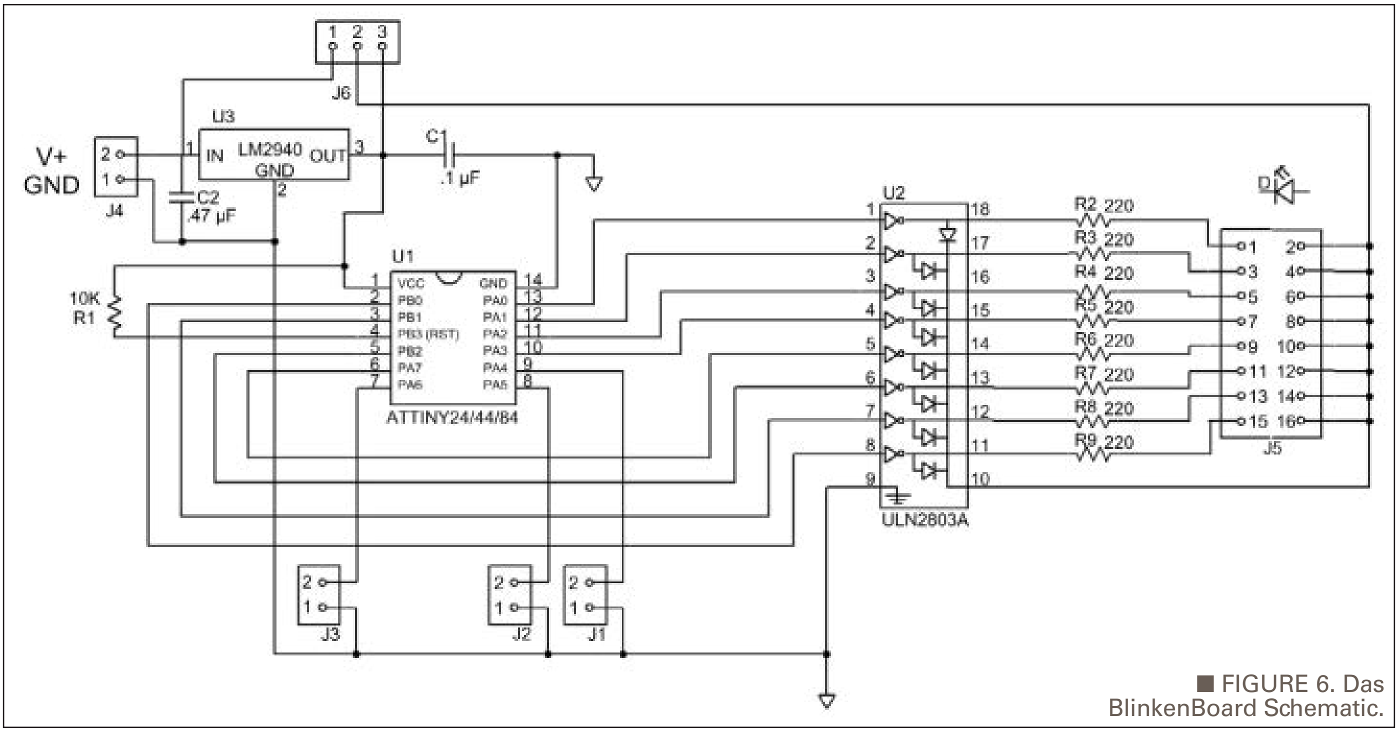
As our research turned up lots of "blinky" LED kits from various vendors, we had to make sure that ours was unique enough to justify building it rather than just buying something already available. As we went through the various scenarios that could benefit from a BlinkenBoard, we decided the key factor would be versatility. We wanted the board to be able to not only turn LEDs on and off, but to set their brightness levels via PWM. We wanted to be able to do more esoteric things such as drive and/or control the speed of standard DC motors, brushless motors, or even handle stepper motors.

We wanted to control both inductive and solid-state relays or drive solenoid valves for pneumatic devices. We wanted to be able to drive CCFT lights and incandescent bulbs. We wanted to be able to experiment with Persistence of Vision (POV) displays or drive speakers to make sounds. We envisioned controlling LED cubes and having the boards communicate via serial commands. And, of course, we wanted the ability to upgrade the system software so the board's role could evolve as future challenges were met.

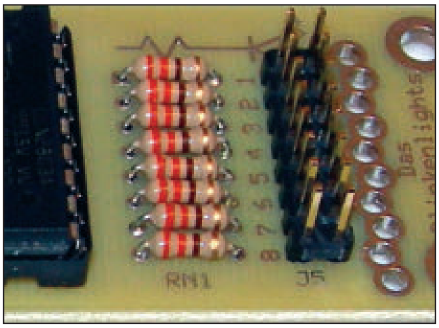


■ FIGURE 7. Rectangular LEDs fitted into .100” spaced holes.

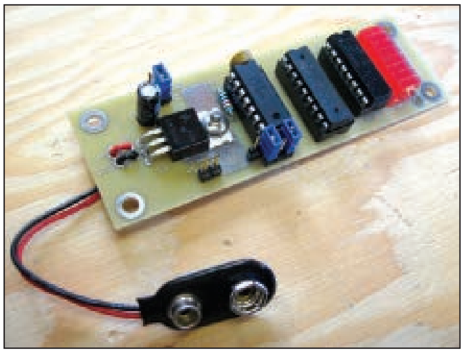
■ FIGURE 8. LEDs attached to the end of ribbon cable.



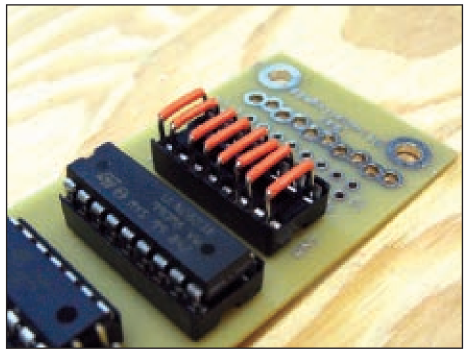
■ FIGURE 6. Das BlinkenBoard Schematic.



■ FIGURE 9. Individual resistors mounted directly on Das BlinkenBoard.



■ FIGURE 10. Completed board with resistor network in DIP socket.



■ FIGURE 11. Resistor network removed and shunts added into socket.

VERY VERSATILE VERSION

So, now that we had the specs, James picked up a previous project of his dubbed the "Generic LED Sequencer" (see Resources) and wrote new, more versatile software to fit the new design. Paul drew up the schematics and laid out a PCB in ExpressPCB (**Figure 3**), I ordered the boards (**Figure 4**), and then each of us took a turn at soldering up one of the prototypes to make sure everything worked.

Paul built a board with the LEDs directly on the board and with power provided by a 9V battery snap. I built a board with the resistors omitted and had it drive a bunch of differing loads. James built one with a .100" 2x8 header and IDC connector pigtail with LEDs on the end. Every single one worked first shot out of the chute!

I want to point out that with the details in this article plus all the software being downloadable from the *Nuts & Volts* website (**www.nutsvolts.com**), you should be able to build one of these boards yourself. However, if you'd rather not go dig for parts and you'd like to take advantage of the bulk buying power the folks at the *Nuts & Volts* store have, we encourage you to stop by the store and order a kit (**Figure 5**).

LET'S HAVE A LOOK AT THE SCHEMATIC

Before we warm up the soldering iron, it's always a good idea to have a look at the schematic to see just what it is we're building. Though the schematic is laid out according to the specifications cited, a quick overview of its configuration and design features will help you to understand your options when it comes to assembly. Refer to the schematic in **Figure 6** and follow along.

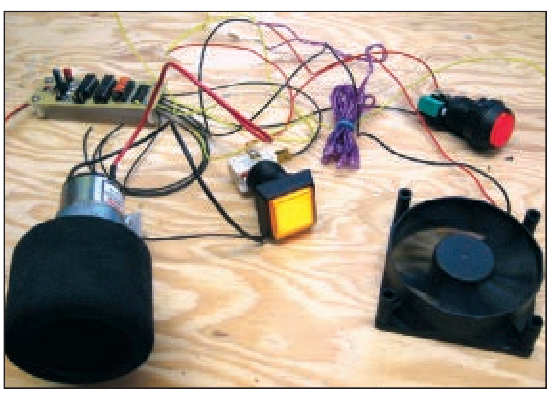
Power comes into the board via J4 and may be provided by a 9V battery snap, tinned leads, or even a 12V PC hard drive power connector. Once on board, V+ is routed to the 7805 voltage regulator (U3) and C2 is used to filter any incoming noise from the power source. Power from the voltage regulator is used to feed 5V to the ATtiny84 (U1). J1, J2, and J3 are .100" header pins and are used to set the mode of operation on power-up and during operation of the board.

PA0-PA3 drive channels 1-4 of the ULN2803A Darlington array and PA7, PB2, PB3, and PB1 drive channels 5 through 8, respectively. NOTE: The seemingly random choice of pins that drives the 2803 was actually very much by design. The above order leaves RST, SCK, MISO, and MOSI unencumbered so that the chip can be programmed while in the circuit board.

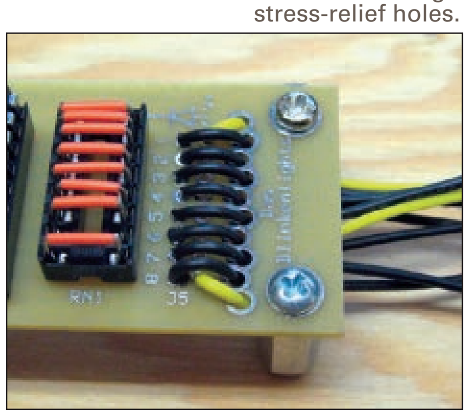
The 2803 then drives eight 220 ohm resistors used to limit the amount of current flowing through J5. J5 is designed to allow you to place eight discrete LEDs in a row on the board for the most compact setup. J6 is used to determine if the LEDs receive voltage from the 7805 regulator or directly from the V+ line. This allows you to choose if you want the regulator burdened with the current draw of the LEDs or if you would prefer the LEDs get their power directly from the voltage source.

AND HOW EXACTLY DOES THIS ALL LAY OUT?

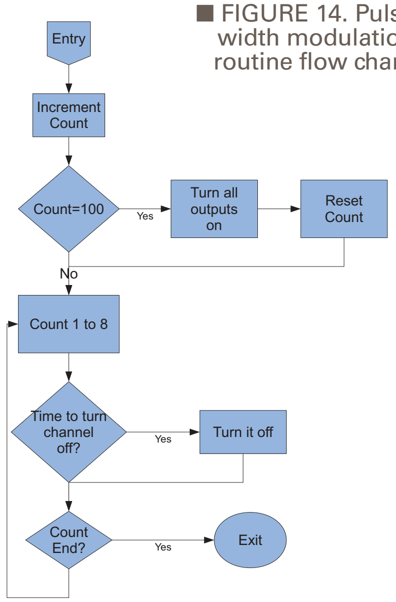
When laying out the PCB, many things were taken into account in



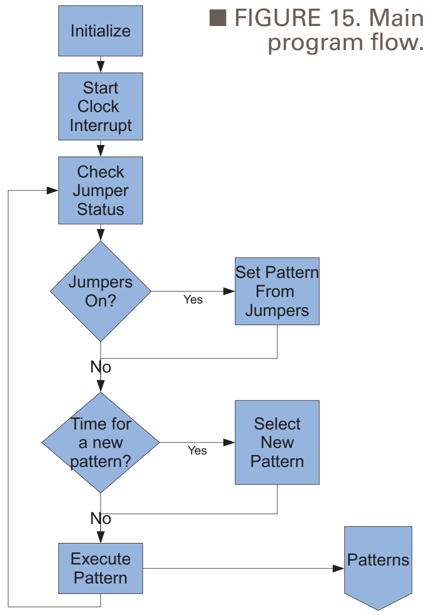
■ FIGURE 12. A collection of non-LED loads Das BlinkenBoard can run.



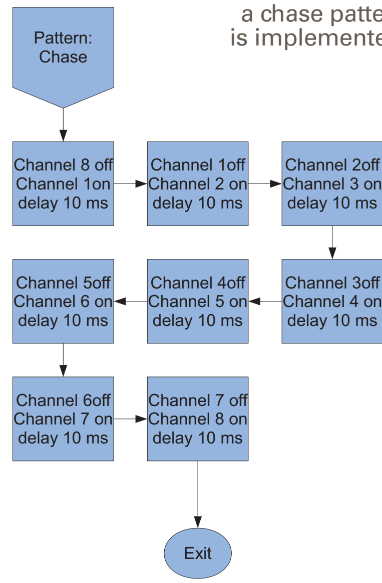
■ FIGURE 13. Das BlinkenBoard with wires threaded through stress-relief holes.



■ FIGURE 14. Pulse width modulation routine flow chart.



■ FIGURE 15. Main program flow.



■ FIGURE 16. How a chase pattern is implemented.

order to make sure the board was as versatile and robust as possible. For example, the J5 connector can be used to hold eight LEDs directly on the board itself (**Figure 7**) or it can be used with a .100" 2x8 header. This way, an IDC style connector and some ribbon cable can be used to extend the load (be they LEDs or other devices) away from the board (**Figure 8**).

Note that the schematic shows eight discrete 220 ohm resistors and some of our prototype boards were indeed built in this manner (**Figure 9**). However, others were completed using a DIP socket with a resistor network (**Figure 10**). Using a socket allows you to change resistance values to accommodate different V+ voltages and/or different types/numbers of LEDs simply by replacing the DIP resistor network. In addition, the resistor network could be replaced by straight-wire jumpers (**Figure 11**) if the load being driven by the ULN2803A does not require current limiting.

For example, in **Figure 12** you can see the prototype board I built with channel 1 connected to an incandescent light bulb, channel 2 connected to a string of 10 high-brightness LEDs, channel 3 connected to another incandescent indicator light, channel 4 is connected to a brushless DC fan motor, and channel 5 is connected to a 12V DC gear motor and wheel. To see a video of all this in action, check the Resources section.

Another feature to make the board durable is the inclusion of stress relief holes along the edges where wires may be attached, such as J5 (**Figure 13**). This way, if the loads connected to the board are mobile and/or they are shifted during

installation or setup, there is a much lesser chance you'll be digging out a soldering iron in the minutes before a show!

THE SECRET IS IN THE SOFTWARE

As mentioned earlier, the software was updated by James from his original generic LED sequencer. This new version defines an array of eight variables to hold a value for the pulse width modulation routine. This routine (**Figure 14**) is triggered by a timer interrupt to service the eight independent channels of PUM. The main flow of the program (**Figure 15**) creates sequences by altering the values stored in this array of eight variables (see **Figure 16** for an example of one of these sequence routines). The code is too long to include here, so please feel free to download and examine the code more closely. James has long wanted to convert me from my Basic programming to C so he went to the trouble of making an interesting and useful "Rosetta Stone" version of the software. This is a document presented in a two-column fashion that compares each of the C routines to a similar routine in pseudo Basic. It is a very helpful document for understanding this code and also to help see the similarities between the languages. I would recommend it for those of you (like me!) who might be thinking of dipping a toe in the waters of C programming. James has released all the software for this project under the GNU public license.

DON'T BLINK! WE'LL BE BACK!

So, as versatility was one of the most important ingredients for this project, I plan to work with James and Paul to come up with updates that will be published in a sidebar in my next few articles. Keep an eye out for some neat new ideas and new software patterns/functions in the coming months. I hope you'll join me in building your own Das BlinkenBoard. If you do and you come up with your own unique and interesting uses, please let me know. As always, you can reach me at vern@txis.com **NV**

continued from page 34

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MARCONI CRYSTAL RADIO KIT

The new My Marconi Crystal Radio Kit from the Xtal Set Society tunes the AM broadcast band. It's a double-tuned tank set and includes an air variable capacitor for antenna tuning. Each LC tank consists of a 250 µH ferrite toroid coil and a 365 pf air variable capacitor. The primary and secondary tanks are nylon-shaft coupled to the front panel and capacitive-coupled to each other. The front panel is covered with a 10 mil lexan plastic sheet with screened black and white graphics on the back, reminiscent of Marconi's Type 106 Radio Tuner.

The tank caps and coils mount on a 10 x 7 x 1/8 inch hardboard chassis, while the antenna condenser and posts for a detector diode mount on the 10 x 6.625 inch front panel. The kit includes chassis, front panel, side rails, metal and nylon hardware, two earphones, two ferrite toroids, a detector diode and capacitors, and an 18 page manual (including schematic and theory of operation).

This kit is ideal for second-set builders and those interested in learning more about coils, tank circuits, antenna matching, diode detection of AM radio signals, and matching of earphones and headphones to a crystal detector.

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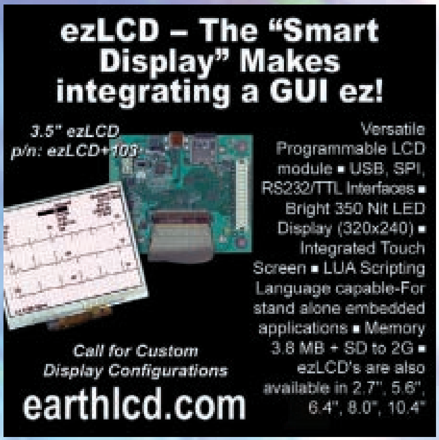
SHOWCASE



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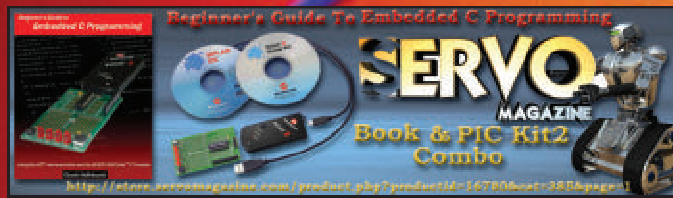

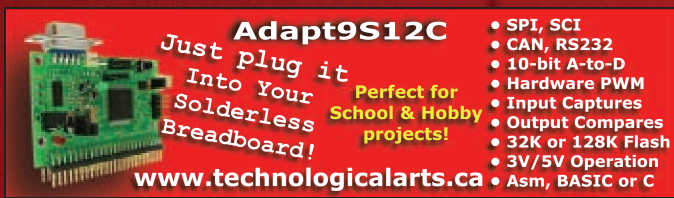

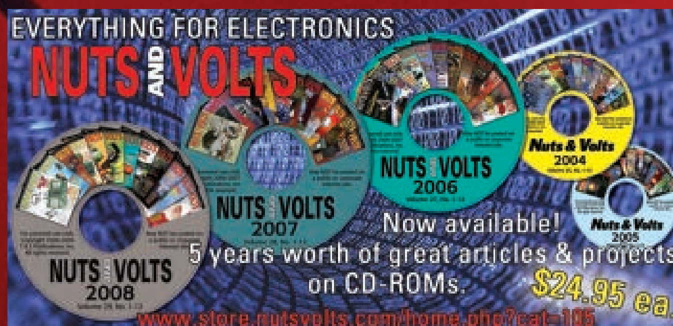

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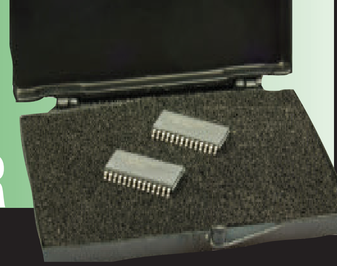


■ BY RON HACKETT

TAMING UNRULY LCDs: PART 2

IN THE PREVIOUS INSTALLMENT OF THE PRIMER, we constructed two stripboard circuits that simplified the interfacing of two different sizes of parallel LCD displays (16 characters by two lines and eight characters by two lines) to our PICAXE projects. Due to the fact that each of these circuits require six dataline connections, they aren't suitable for use with the smaller PICAXE processors. Directly interfacing a parallel LCD display with an 08M processor is impossible because the little 08M doesn't have enough I/O lines and even though the 14M does have sufficient I/O capability, its program memory would be significantly used up by the driver software, leaving little room for other program tasks.

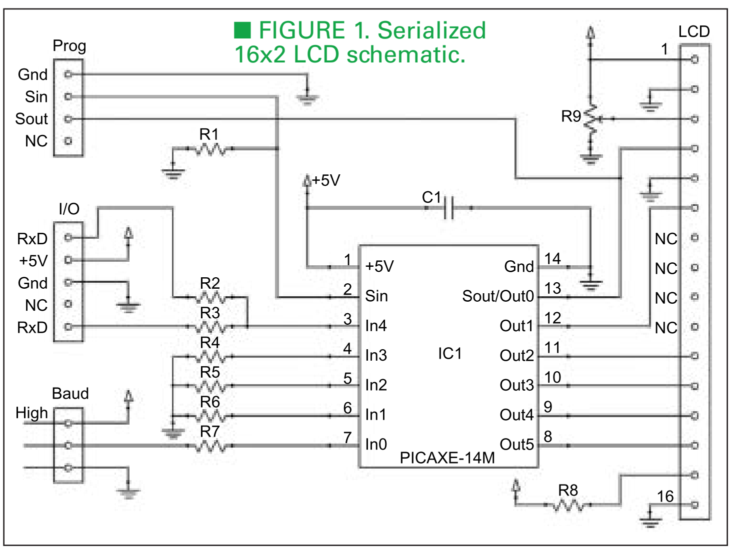
This month, we're going to solve that problem by dedicating a 14M processor to the task of accepting a single line serial input from our master processor (or any PICAXE project, for that matter) and using that input to drive the parallel LCD. The 14M is the perfect processor for this project. It has more than enough I/O lines and program memory for the task at hand and it's cheap enough that you can construct two or three complete "serialized" LCDs for the price of one commercial display. Besides, it's much more fun to build something than it is to purchase a relatively expensive ready-made unit, right? Before we get started, I want to let you know about some new products.

NEWS FLASH

Revolution Education recently announced the availability of their new "X2" line of microcontrollers. The 40X2 and 28X2 versions are available now, and a 20X2 chip should be available soon. There are too many new features to list them all here, so I'll just provide a brief rundown of the features that are the most exciting. For more information, see the PICAXE X2 Range Released thread on the PICAXE Forum (**www.picaxeforum.co.uk**/).

- Clock speeds as high as 64 MHz
- Up to 4,000 lines of Basic code
- 56 general-purpose variables (b0-b55 or w0-w27)
- Up to 256-byte general-purpose RAM (peek, poke, and @bptr commands)
- Up to 1,024 byte scratchpad RAM (put, get, and @ptr commands)
- Two or three (depending on which X2 chip) new hardware interrupt pins
- Up to 12 ADC inputs
- Support for programs stored in external EEPROM

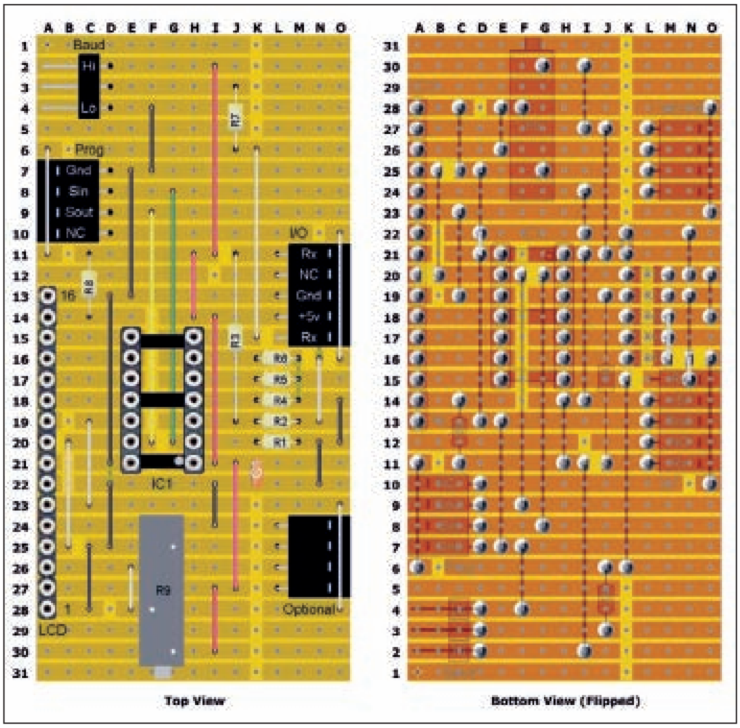
I'm especially interested in the new low voltage (1.8V–3.6V) PICAXE-28X2. It looks like it will be an excellent processor for battery-powered projects. As soon as I get my hands on one, I'll let you know what I think.



■ FIGURE 1. Serialized 16x2 LCD schematic.

CONSTRUCTING A STRIPBOARD CIRCUIT TO SERIALIZE A 16x2 LCD DISPLAY

Let's start with a 16x2 display because the stripboard construction is a little easier than that of the 8x2 display. **Figure 1** presents the schematic for our serialized 16x2 LCD



■ FIGURE 2. Serialized 16x2 LCD stripboard layout.

display. Although it's a fairly simple circuit, there are a couple of points that may need clarification. The first one is the five pin breadboard connector. As you can see, two of the pins are labeled "Rx." While this may seem a little odd, there's a good reason for setting it up this way. If you look at the order of the connections and compare it to pins 21-17 of our 28X1 master processor, you will see why I chose this arrangement. When the stripboard circuit is constructed, its five pin breadboard connector can be inserted into a breadboard directly in line with pins 21-17 of the 28X1. However, only one of the two "Rx" pins on the stripboard should be connected at any one time. That's one of the reasons that the connector is a female header. This enables us to insert a four pin male header into either the left-most four sockets or the rightmost four sockets of the female header. (Accidentally using a five pin male header won't do any damage, but the LCD will definitely not function correctly.) Of course, as we have discussed in previous projects, the male header must be long enough on each end to make a solid connection. Suitable headers are available on my website (**www.JRHackett.net**).

The purpose of this somewhat unusual arrangement is to provide the flexibility of using either output0 (pin 21) or the hserout pin (pin 17) of the 28X1 as the serial output to the LCD display. Whichever one you choose, the +5V and ground connections line up appropriately so that no jumper wires are needed for the interface.

Once the pinout arrangement and connection options of the breadboard connector are clear, the remainder of the circuit is fairly straight forward. Resistor R1 should be familiar by now; it ties the 14M "Serin" line to ground so that the circuit can function properly without having the complete PICAXE programming circuit on the board. Resistors R2 and R3 protect the circuit (and the master processor) from damage if a five pin male header is accidentally used; resistors R4–R6 simply tie the 14M's unused inputs to ground; resistor R7 is the current limiter if you are using a backlit display. (If so, don't forget the discussion in the previous installment of the Primer about the necessary precautions.) If you want to experiment with different displays, you can also replace resistor R7 with a four pin female header, which would enable you to change resistors without de-soldering/re-soldering the connections. (See my completed board in Figure 5.) Resistor R8 is used in the baud rate selection circuitry which we'll talk about when we get to the software for our project. Finally, potentiometer R9 is the contrast adjustment for the display. As you can see in the schematic, we're using the same four pin connector for our programming adapter that we used in the IRMB projects. We will be using this connector in several upcoming projects, as well. Once you have a clear understanding of the circuit schematic, we're ready to move on to the stripboard layout, which is presented in **Figure 2**. If you want a larger version to work with as you construct the circuit, it's available on my website (**www.JRHackett.net/projects.shtml**). The corresponding parts list is presented in **Figure 3**. As usual, all the required parts (including the larger stripboard) are available on my website but I'm sure you already have many of them on hand by now.

The layout isn't complicated but it is significantly larger than any of our previous stripboard projects, so it would be a good idea to carefully check (and re-check) your work throughout the construction process.

There are only a couple of points that I want to mention before we begin construction. First, the four pin female header in the lower right hand corner of the stripboard serves no electrical purpose. Its only function is to provide some stability for the LCD assembly when it is inserted into a breadboard. Simply insert a male header and connect it along with the breadboard connector to keep the LCD board from "wobbling" excessively. A two or three pin right-angle female header would work just as well for this purpose, but four pin was the smallest I had available — use whatever you have.

The jumper wires spanning each of the right-angle female headers also

ID	PART
■ C1	.01 µF bypass capacitor
■ IC1	14-pin (machined) DIP socket
■ R1	100K resistor (1/6 W)
■ R2-R7	4.7K resistor (1/6 W)
■ R8	*See text
■ R9	10K potentiometer
■ LCD	16-pin straight female header
■ Prog	Four-pin right angle female header
■ Baud	Three-pin right angle male header
■ I/O	Five-pin right angle female header
■ Optional	Four-pin right angle female header
■ —	Two-pin shunt
■ —	Jumper wire
■ —	Stripboard: 31 traces, 15 holes each

■ FIGURE 3. Parts List for stripboard circuit.

serve no electrical function. As we discussed last time, they simply protect the header from the strain of repeated insertions and extractions during long-term use. If you are using a backlit LCD, be sure you have installed the correct size current-limiting resistor for your display. Finally, there should be enough room at each of the bottom corners of the stripboard to drill a hole aligned with the holes in your LCD display should you want to fasten the two boards together.

TESTING THE LCD DISPLAY BOARD

Throughout the remainder of this project we will be using three programs with our serialized LCD display (LCDtest.bas, LCDdriver.bas, and SeroutToLCD.bas) which are all available for download from my website. You may want to download them and print out a copy for reference during the following discussion. The first program (LCDtest.bas) simply displays a blinking message on the LCD to be sure the board is functioning correctly. In order to install LCDtest.bas (or any program) to the LCD board, you will need the standard four pin programming adapter we used previously with the IRMB project. If you don't have one available, refer back to that project for construction details. If you prefer, a PC board version is available at my website; just look for the UPA4x4 programming adapter. If you do build the PC board version, be sure to construct the option that has a single four pin header that matches the pinout of the connector on the LCD board.

To test the LCD board, plug it into a breadboard with a 5V supply and connect the power and ground lines to the appropriate pins on the board's breadboard connector. (At this point, it doesn't matter which position the two pin shunt occupies on the BaudRate jumper — we'll get to that shortly.)

Once you have installed the LCDtest.bas program on the LCD board, you should see the test message blinking about once per second. If not, adjust the contrast potentiometer until the message appears. The easiest way to do this is to turn it counter clockwise until you hear the faint clicking sound that indicates it is at one end of its adjustment, then turn it back a little. If you still do not see the blinking test message, you will need to re-check the wiring on the board for possible problems.

SERIALIZED LCD DRIVER SOFTWARE

When you are satisfied that your display board is functioning correctly, we're ready to move on to setting up a serial communications link between our master processor and the LCD board. In order to do so, we will need two separate programs: one for the 14M on the LCD board (LCDdriver.bas) and one for the 28X1 (SeroutToLCD.bas). Before you install the programs and test the system, I want to discuss the LCDdriver.bas program briefly.

First of all, this is just one possible driver for the LCD board. You may well decide to modify it to better suit your needs but before you do, I want to explain a little about how I arrived at the current version of the software.

The most important fact to keep in mind when developing driver software for the LCD board is that the 14M's "serin" command stops all processing until the specified number of bytes has been received. In other words, if the driver software is written to receive four bytes of data and the 28X1 only transmits three bytes and then goes on about its business, the 14M will be waiting at the point of the serin command without displaying anything at all. To avoid this problem, I have decided to always transmit and receive the same size packets of data. For this purpose, I use a standard packet length of nine bytes. I'm sure other packet lengths would work just as well, but I like to use nine bytes because that length also works well for 8x2 displays.

The first byte in a packet is always a command byte because we usually need to specify the location at which we want to begin displaying the data. For a 16x2 LCD display, the first location in line 1 is always specified by a command of 128 and the commands for each successive location simply increment by one. The same pattern applies to line 2; its first location is specified by a command of 192 and the commands increment across the line. However, it's important to remember that whenever a character is displayed, the location for each of the subsequent bytes is automatically incremented. In other words, once you have specified the starting location, the rest is handled by the HD44780 driver on the LCD display.

With this information in mind, let's take a quick look at the important points in the LCDdriver.bas program. First of all, the two subroutines in the program (one that initializes the LCD display, and one that outputs a byte to the display) are very similar to those we used last time. The only difference is in the "OutByte" subroutine where I combined and simplified the earlier "OutCmd" and "OutTxt" subroutines into one routine by using a slightly different approach to distinguishing between a command byte and a data byte. This time, I relied on the fact that all printable ASCII characters have values between 32 and 127. Therefore, if an incoming byte has a value less than 32 or greater than 127, it must be a command; if not, it must be a data byte. The "if" statement at the beginning of the OutByte subroutine implements this logic and appropriately defines the display's "RSbit" line. Also, there are two aspects of the main "do...loop" in the driver software that require a brief explanation. As you know, we included a BaudRate jumper on the LCD board. Its function is to allow us to choose one of two baud rates (high or low) by simply moving the jumper rather than needing to reprogram the board to accomplish this change. The initial "if" statement in the do...loop simply tests whether input0 (to which the jumper is connected) is high or low, and then sets up for receiving the nine incoming bytes at the appropriate baud rate. As you can see I'm using 4800 as the high baud rate and 2400 as the low rate, but you could change these to whatever you want. Just remember that 4800 is the fastest the

NAME	FUNCTION	VALUE
■ D0	Display Off	8
■ D1	Display On (cursor off)	12
■ DC	Display Clear (cursor home)	1
■ C0	Cursor Off (display on)	12
■ C1	Cursor On (no blink)	14
■ CB	Cursor Blink	15
■ CH	Cursor Home (display not cleared)	2
■ L1	Cursor Left one position	16
■ R1	Cursor Right one position	20
■ Q1	Cursor at Quadrant 1	128
■ Q2	Cursor at Quadrant 2	136
■ Q3	Cursor at Quadrant 3	192
■ Q4	Cursor at Quadrant 4	200

■ FIGURE 4. Selected HD44780 LCD commands.

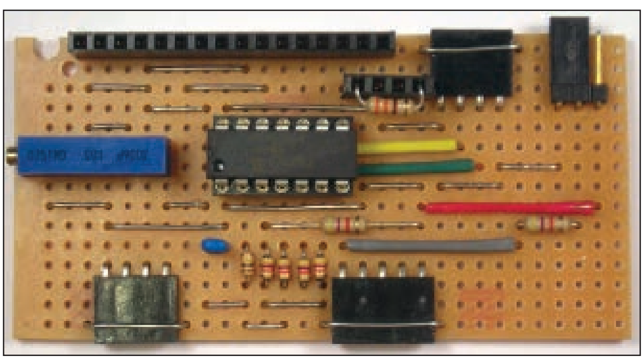
14M can handle at its 8 MHz internal clock rate. Using nine separate variables to receive the nine incoming serial data bytes may seem a little wasteful (or even crude, if you care about program elegance) but the 14M will never be doing anything else, so there is no harm in squandering its variable resources. What's more important here is that receiving all nine bytes in one serin statement is by far the fastest way to get a data packet into the processor. Every other method I tried necessitated the inclusion of "pause" statements in the master processor's software in order to slow it down enough for the system to function correctly. If you come up with another way to accomplish "pause-less" transmissions, let me know.

SENDING DATA FROM A MASTER PROCESSOR TO THE LCD DISPLAY

The software that the master processor needs to send data to the serialized LCD display is super simple. The only requirement is that it must send the data in the same nine-byte packets that the LCD display expects to receive. Failure to do so will result in garbled data on the display or none at all. Before we take a look at our simple master processor program (SeroutToLCD.bas), let's discuss some of the HD44780 commands that we have at our disposal. The HD44780 driver supports a surprisingly wide variety of commands, but for the sake of brevity I'm going to limit our discussion to a subset that I have found to be the most useful. (If you are interested in the other HD44780 commands, see the documentation for your specific display.)

Figure 4 presents the standard HD44780 commands that I have chosen. It also includes the two character name that I use for each command. (Unfortunately, I wasn't able to use "CR" for "cursor right one position" because the PICAXE compiler has reserved CR for the ASCII carriage-return character.) In any program that involves outputting data to an LCD display, I just define each of the names as constants of the corresponding value. It's much easier to remember the command "names" than their corresponding values.

Actually, the last four entries in Figure 4 aren't official HD44780 commands; I just made them up to simplify things for myself. Since I have standardized on nine byte packets (one command + eight more bytes), I also have decided to think of a 16x2 display as having four quadrants: the beginning of line 1 is Q1; the middle of line 1 is Q2; the beginning of line 2 is Q3; and the middle of line 2 is Q4. By appropriately defining the value of each quadrant, I don't need to remember the command value associated with each location, just its name. Of course, there will be times when you want to send fewer than eight data bytes to the display. This can be accomplished by "padding" the transmission with commands that produce no visible difference in the display. One command I like to use for this purpose is the "R1" command (cursor right one position; see Figure 4). Since I generally keep the cursor hidden, moving it to the right produces no visible change in the display. So, suppose we have already defined LCD as 0 (because it's connected to output0) and have also defined the command constants listed in Figure 4. Then, if we wanted to display "Yes" on the LCD starting at the third position in line 1 (i.e., location 130), either of the following serout commands would serve that purpose: serout, LCD, (Q1, R1, R1, "Yes", R1, R1, R1) or serout, LCD, (130, "Yes", R1, R1, R1, R1, R1). Naturally, spaces can also be used to pad a transmission, but they will over-write whatever had been previously displayed in the corresponding locations. If that's the desired result, "printing" spaces is the easiest way to accomplish it.



■ FIGURE 5. Completed 16x2 LCD board.

In any program that sends serial data to an LCD display, I define the 13 constants listed in Figure 4, usually by copying them from an earlier program and pasting them into the new program. The PICAXE documentation mentions a "#include" directive, but it hasn't yet been implemented. When it is, the process will be even simpler — you could just write a short file that only contains your LCD constant definitions and then add the appropriate #include directive at the beginning of each program that uses a serial LCD display.

PUTTING IT ALL TOGETHER

At this point, we're ready to test the entire system. **Figure 5** is a photo of a completed 16x2 LCD board and **Figure 6** shows it installed on my 28X1 master processor breadboard. In that photo, you can see how the LCD board's five pin connector lines up with the 28X1's pins. As you can also see, the four pin male header that we discussed earlier is inserted into the leftmost sockets of the five pin female header, so we will be using

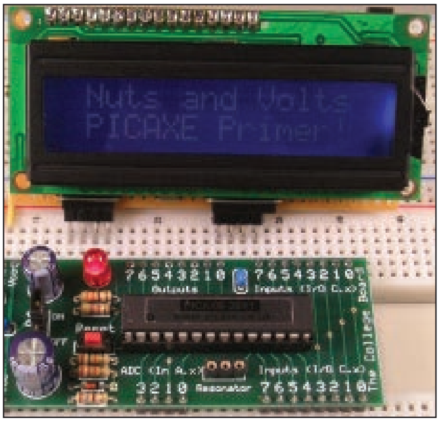
the 28X1 output0 to communicate with the LCD board. What you can't see in the photo is that I have connected the power and ground pins from the LCD's breadboard connector to the appropriate power rails on the breadboard behind the LCD. If your 28X1 chip is plugged directly into your breadboard, those connections will already be in place for the 28X1 itself; if you are using the College Board, don't forget to add them.

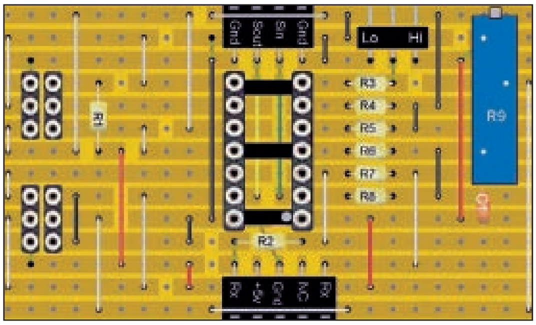
Download the LCDdriver.bas program to the 14M on the LCD display board and download the SeroutToLCD.bas program to your master processor. You should see the two different messages alternating on the LCD display. If not, turn off the system power for about 10 or 15 seconds and then try again. If the display still is not correct, you will need to re-check the connections between your master processor and the LCD board. As usual, if you're really stumped, email me with the details (Ron@JRHackett.net) and I'll see if I can help.

Once you have your serialized LCD display working properly, you can use it with any project that involves an LCD display. You may also want to experiment with some of the more advanced LCD commands available on the HD44780 displays. For example, you might want to try your hand at scrolling the display to allow lines longer than 16 characters (see the HD44780 documentation for all the commands that are available). Also, if you want to serialize a different size display, the exact same circuit can be used. The only thing that needs to be changed is the stripboard layout. For example, **Figure 7** shows a completed stripboard layout suitable for the Hantronix 8x2 displays. If you are interested in constructing one, a large size (front and back) layout is available for downloading on my website.

That's all we have room for this time. See you in August. **NV**

■ FIGURE 6. 16x2 LCD board in action.





■ FIGURE 7. Serialized 8x2 LCD stripboard layout.

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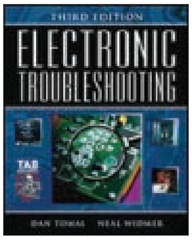

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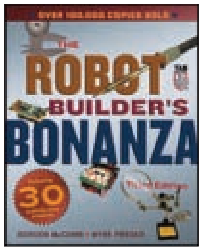

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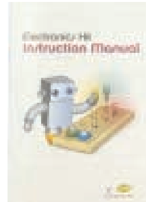

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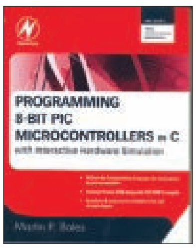

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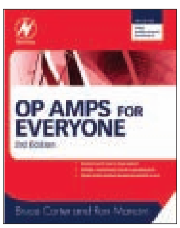

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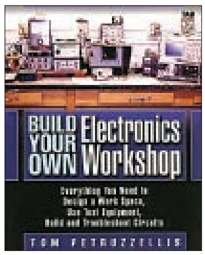

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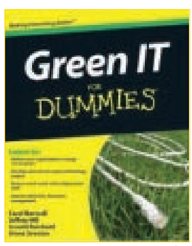

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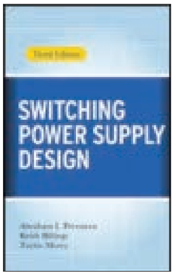

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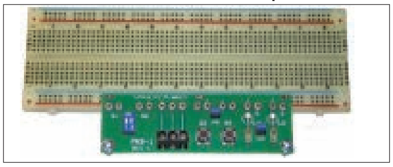

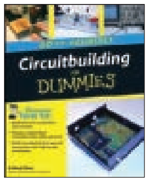

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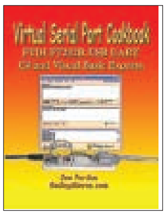

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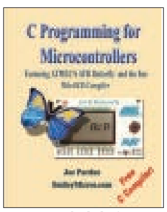

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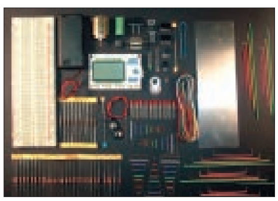

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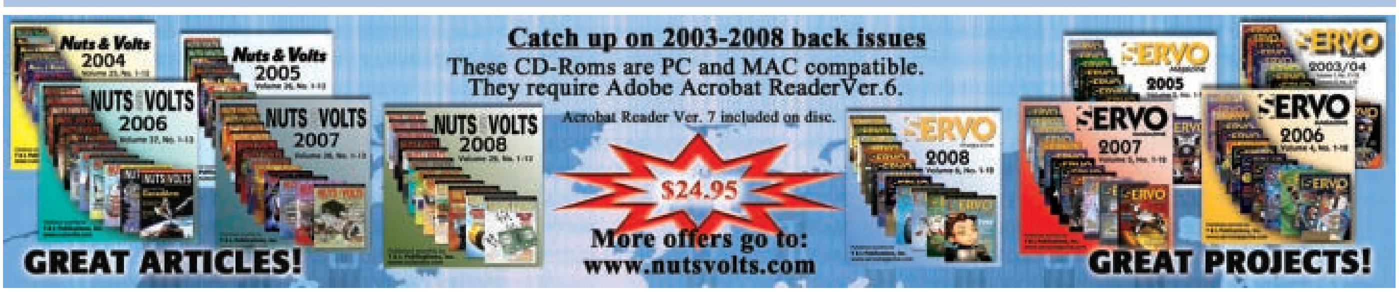

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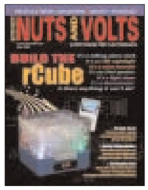

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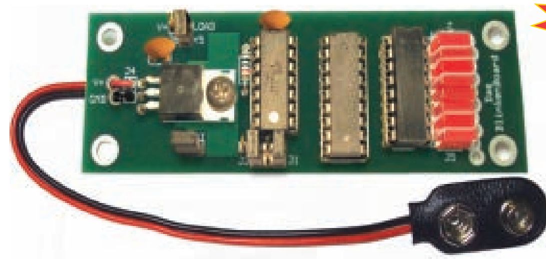

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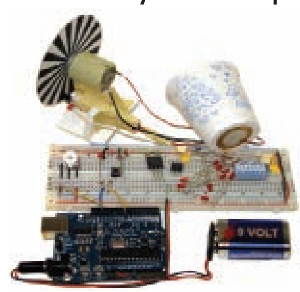

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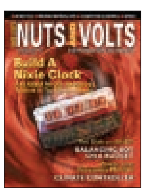

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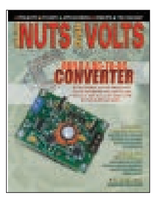
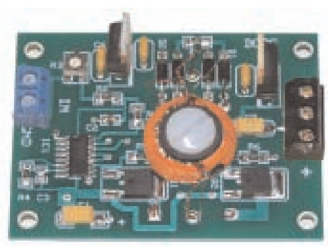


As seen on the March 2009 cover

Wind Your Own Transformers and Build a DC-to-DC Converter



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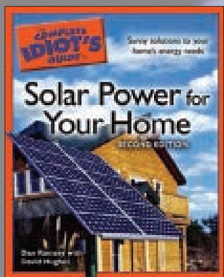
Publish Date: May 2007



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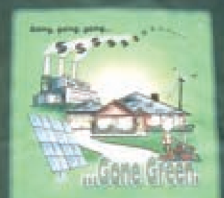

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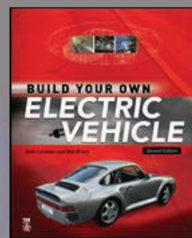

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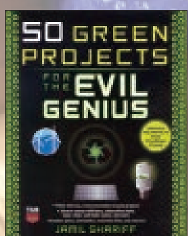

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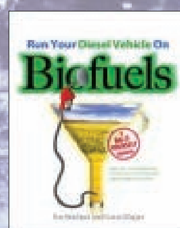

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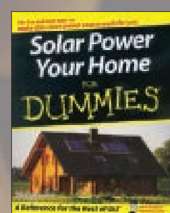
by Rik DeGunther

Publish Date: Dec 2007



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123 PIC Microcontroller Experiments for the Evil Genius

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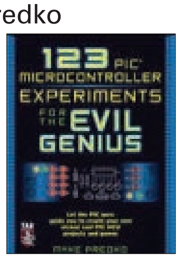

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READER FEEDBACK

continued from page 10

analog/digital "code models" for behavioral simulation, and Cider (previously CODECS, from UC Berkeley/Oregon State Univ.) which added semiconductor device simulation. The integrated circuit industry adopted SPICE quickly, and until commercial versions became well developed many IC design houses had proprietary versions of SPICE. Today a few IC manufacturers, typically the larger companies, have groups continuing to develop SPICE-based circuit simulation programs. Among these are ADICE at Analog Devices, LTspice at Linear Technology, Mica at Freescale Semiconductor, and TISPICE at Texas Instruments. (Other companies maintain internal circuit simulators which are not directly based upon SPICE, among them PowerSpice at IBM, Titan at Qimonda, Linx at Intel Corporation, and Pstar at NXP Semiconductor.)

*To answer your question, the analog SPICE simulators can incorporate "digital" functions (which we covered in the series). This is very helpful for circuits that are both analog and digital (such as an analog comparator that outputs a logic signal). For larger logic circuit simulations, the industry uses other simulation tools. The most popular is called VERILOG (licensed from Cadence). It's similar to the C languague and used to construct (and verify) complex logic such as FPGAs. (**http://en.wikipedia.org/wiki/Verilog**).*

While Verilog is used for complex simulation, simple digital simulation can be done with IBIS tools. It's common for analog IC vendors to issue IBIS models along with PSPICE models.

*Here's the wikipedia entry: **http://en.wikipedia.org/wiki/Input_Output_Buffer_Information_Specification***

Peter Stonard

MIS-LINKED

Regarding my "Inductive Proximity Sensor" article in the March issue ... there was a slight error on the web link that should be corrected.

The link that has **www.obex.parallax.com** should read **obex.parallax.com** instead. This was my fault. It was actually a placeholder in the article I wrote and the template that I was using had the incorrect address.

The above link (**obex.parallax.com**) is correct and will get the user to the object exchange. The Direct link to the actual software within the object exchange can be found at **obex.parallax.com/objects/416/**.

I apologize for any inconvenience this may have caused.

Beau Schwabe

TECH FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and NO GUARANTEES WHATSOEVER are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com *All diagrams should be computer generated and sent with your submission as an attachment.*

QUESTIONS

To be considered, all questions should relate to one or more of the following:

1. Circuit Design
2. Electronic Theory
3. Problem Solving
4. Other Similar Topics

- Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).
- Include your Name, Address, Phone Number, and email. Only your Name, City, and State will be published with the question, but we may need to contact you.
- No questions will be accepted that offer equipment for sale or equipment wanted to buy.
- Selected questions will be printed one time on a space available basis.
- Questions are subject to editing.

ANSWERS

- Include in the subject line of your email, the question number that appears directly below the question you are responding to.
- Payment of $25.00 will be sent if your answer is printed. Be sure to include your mailing address or we cannot send payment.
- Only your Name, City, and State, will be printed, unless you say otherwise. If you want your email address included, indicate to that effect.
- Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

DC Motor and Inverters

Can I run a permanent magnet 90 VDC motor on a 1,500W inverter? I need to reverse the motor and was going to run the inverter output through a full wave rectifier. The motor draws about eight amps.

#6091 **Bill E.**
Warren, OH

Three Volt LED Solar/Charger

Most, if not all, outdoor pedestal lights are 1.5 volts with a very weak LED. With the advent of super bright >10,000 mcd white LEDs, we need a circuit we can drop in (after gutting the old one) that will give a meaningful light source. I entertained a Maxim DC-DC step-up but the existing circuits are current limited. So, how about a 3.x solar source, photocell, a pair of 1.5 VDC batteries, and the charger circuit with photocell switch?

#6092 **Ron Spatafora**
Plano, TX

Autoranging Digital Panel Meter

Does anyone know of a self-contained, autoranging digital panel meter? There are lots of fixed, 200 mV range, self-contained digital panel meters that simply require a power supply and appropriate voltage divider to measure a fixed range of input voltages. I would like to measure from 1m VDC to 400 VDC with three or four digit accuracy. Or, is there a way to make a self-scaling, autoranging voltage dividing, input circuit that would then utilize a standard self-contained panel meter to accomplish the same task? There are many good quality DMMs that are fully autoranging, but they are very difficult to disassemble and implement into a stand-alone system. Most have auto-power-off circuits and other features that make them too cumbersome to implement.

#6093 **Paul**
Rocklin, CA

Monitor Home UPS

I would like to be able to use an oscilloscope PC application to monitor the 120/240 output of my UPS. I found a couple of applications that utilize the PC's sound input.

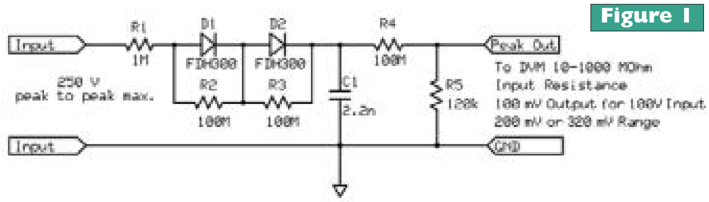
Can the 240V output be effectively and safely reduced to the voltage level of the PC mike input?

#6094 **Curt Timmerman**
Big Lake, AK

Triac Controlled Light Switch

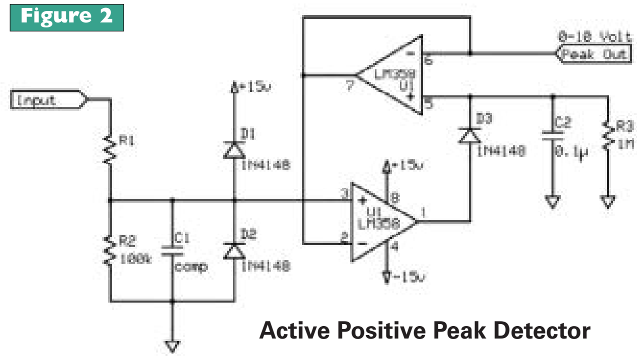
I'm looking for a circuit to run a low wattage 120 volt incandescent light. The source will be a Parallax BASIC Stamp II microcontroller (5V @ 30 mA per I/O) and the circuit needs to be opti isolated. I'd like to use a triac if possible. The light will be off for short periods of time (two to five

Figure 1



Passive Positive Peak Detector Probe

Figure 2



Active Positive Peak Detector

seconds) and on for about a minute at a time.

#6095 **David Milsop**
Humble, TX

24 Hour Counter

I need to build a 24 hour, battery-operated counter with a 2" readout (LED would be okay) that will have the capability to be manually adjusted up/down and reset to 0.

#6096 **German Juarez**
Santa Ana, CA

>>> ANSWERS

[#2098 - February 2009]
Peak Reading Voltmeter

How can I build a peak reading voltmeter or add-on unit for a VOM to read the peaks of a DC pulse? When troubleshooting ignition systems on motorcycles and marine engines, the peak voltage supplied by the various coils needs to be checked. A regular VOM always reads low. How can I catch the peaks?

With RPM as much as 14,000 and as many as 12 pulses per revolution, we are talking very short pulses. Testing is normally done at a cranking speed of 200 to 300 RPM.

#1 A passive peak probe is shown in **Figure 1**. This circuit may be more than adequate, but there are some issues which need to be considered. Most modern digital multimeters (DMM) do not have a constant input resistance on DC. They may have >1,000 MΩ on their lowest range, which drops to 10-11 MΩ on their higher ranges.

Therefore, the load current changes by two to three orders of magnitude when the meter switches from the lowest range to the next higher one. Older meters have a constant such as 1 MΩ/V which makes the load far more predictable, but considerably higher. The circuit should be protected against moisture to maintain accuracy due to the high resistances.

A peak reading meter is easily constructed. You may use the peak follower circuit published in T. Brown's *Handbook of Operational Amplifier Applications*, p. 87 (Burr-Brown), updated by Texas Instruments a few years ago (SBOA092A). The circuit — although simple — will always read a diode drop low. National Semiconductor published a circuit in AN4, which is better suited and will be considerably more accurate.

A version of this circuit is shown in **Figure 2** with input protection and a voltage divider. To accurately transmit a pulse through a voltage divider, the capacitance ratio needs to match, as well. A negative peak detector can be built if all diodes are reversed and the input protection is rearranged.

Walter Heissenberger
Hancock, NH

#2 The problem of reading amplitude of high voltage narrow and variable pulses cannot be solved by using a "peak voltmeter" as you ask for. The best option is to use an oscilloscope which is easy to synchronize and offers the best way to measure pulse amplitude, pattern, etc., over a wide frequency range.

I use a Velleman HPS-40 for many tasks; at **www.elexp.com** you can get it for $280. It also functions as a digital voltmeter and can be run on an internal battery. I can also measure < one microsecond pulses if needed, as well as use it as a data logger with 10-minute sampling, etc.

Jiri Polivka
via email

[#2099 - February 2009]
USB HDTV Tuner Hack

How hard it is to rewire or modify a USB HDTV tuner to work with a portable DVD player to watch HDTV programming from it or any other applications like making a portable HDTV tuner with a battery power source?

The USB HDTV tuner can be used as a portable TV only when connected to a laptop, which would also provide the screen for the picture. USB cannot be used without a computer, and a USB tuner only provides a digital signal.

To use the portable DVD player as a portable HDTV, try finding a DTV tuner box that is powered by DC and comes with a black cube transformer that plugs into it instead of an AC line cord. It's then possible to use batteries instead. The DTV tuner boxes are specifically meant for any analog TV screens and they are cheap; possibly even free if you can get a "government DTV box coupon." These boxes need an antenna, but short rabbit ears, UHF loops, or small UHF beams may be sufficient.

I haven't seen any small portable HDTVs and if they don't exist, it may be because (as I heard an HDTV broadcaster say) there is an issue with receiving HDTV broadcasts while in motion because of doppler effects on the frequency and continuously changing multiple signal paths which would constantly black out the reception in a car.

But that is a problem that they know can be fixed. It just might not be immediately, unless you are lucky to have a tuner that already can deal

with that problem.

William Como
Bethpage, NY

[#20910 - February 2009]
Inquiring Minds Want To Know!

Transformers, motor stators use stacks of thin (approx. 1/32") steel plates. Is this for manufacturing economics or is there a physics reason for using stacked plates?

Will using 1/16" plates instead of 1/32" plates affect performance? How much less efficient is aluminum wire versus copper for making transformers, stators, electromagnets?

Are there small solid-state relays capable of handling high voltage/high current surges through the switches (rail gun application)?

Thin stacks of steel or iron plates are chosen for transformers and motor cores to reduce eddy currents. In transformers and even in DC motors, the current applied to the coils in the device reverses direction often. This action induces a significant voltage in nearby metal, and if a solid rather than a "laminated" iron core is used, currents will flow through the iron in a direction that opposes the original magnetizing force. This current flow would reduce the effective force of the magnetic field, and the current flow would generate heat and waste energy as it passed through the resistance of the iron or steel. There are still some eddy currents produced in the layered cores, but much less than in solid cores. Thicker plates allow more eddy currents than thin plates, so the thin plates waste less power. Eddy currents flow in circular paths and the layers tend to force it into smaller paths.

One-thousand feet of copper wire of size #14 has about 2.6 ohms of resistance. The same length and size of aluminum wire has about four ohms. This is approximately 50% more resistance. One ampere flowing through that length of #14 copper would drop 2.6 volts and waste 6.76 watts. One amp flowing through the aluminum would drop four volts and waste 16 watts in the form of heat. All other metals except silver would have more resistance and waste much more energy. Many popular solid-state relays are designed with triacs which work very well with AC rather than DC. You may need some HGTP2N120BN IGBTs like the one in *Nuts & Volts* (Feb 2009 on page 29) which is rated at maximums of 1,200 volts and 12 amps controlled by your logic circuits for the rail-gun application. The precise on-and-off timing that you need would be improved over a "ready made" solid-state relay.

Bill Bradrick
Pittsburg, KS

[#3091 - March 2009]
Plasma Speakers

*Does anyone have any schematics and info on building a plasma speaker? I have seen **www.instructables.com/id/Build_A_Plasma_Speaker/**, however, some of the details regarding the driver and other info is not stated.*

There was an article many years ago in an electronics magazine of the day (it could have been *Popular Electronics* or *Radio-Electronics*) about making a speaker using an oxy-acetylene torch. I just did a Google search and didn't turn up the magazine article, but I did find a URL where someone comments on the fact they built one: **www.edn.com/blog/1700000170/post/90041409.html**. They say that they used a torch, a salt water wick, and a 5 kV step-up transformer.

If you search for plasma speaker acetylene on Google, you might find what you want. For example, **www.articlesbase.com/music-articles/history-of-plasma-arc-speakers-262654.html**. is a "History of plasma speakers," or maybe even better is **http://forums.bit-tech.net/showthread.php?t=142102** where they talk about Tesla coils as speakers.

Rusty Carruth
Tempe, AZ

[#3092 - March 2009]
Detecting a Fault on a High Side OMNIFET

I am designing an H-bridge motor driver using two STMicro L6384 drivers, and four VNV35N07 OMNIFETs. Since the OMNIFETs are internally protected, I hope to avoid using sense resistors for fault detection. Please suggest an elegant way to detect faults on the high side. If a high side VNV35N07 has clamped the gate, what is a good way to detect this and produce a 5V logic level signal referenced to ground? Power supply to the H-bridge will usually be 24 VDC, though it could be anywhere from 6V to 30V.

There are several ways you can measure the positive supply rail current, either through non-contact or shunt resistance (circuit board trace will do).

1. Hall sensors or magneto resistive sensors sense the current in the conductor magnetically and convert it to an output signal. Allegro Micro has the ACS750LCA-075, Melexis the CSA-1V or MLX91205, and an evaluation kit available. Zetex has a magneto-resistive sensor — see AN20, AN37, and AN32 in their *Current Measurement Applications Handbook*.

2. Current transformers. These are frequently used as a current monitor in switched mode power supplies. See Pulse Engineering for these transformers. Their latest arrangement is called a Rogowski coil, essentially a toroid transformer with a single turn primary, a secondary wound on a toroid, but no magnetic core — basically a wide band air transformer with good coupling and rejection.

3. Current shunt with either a flying capacitor arrangement (Linear Technology LTC1043 page 15, 18V max. rating) or a current mirror level translator. The voltage drop is converted to a current; the Zetex ZDS1009 (see AN37) is an example. This allows you to establish a ground reference easily. The flying capacitor arrangement is one of the most accurate ways and will fit extremely well to the new generation of ADCs, where capacitor voltage doubling, quadrupling, and more can be performed in the input stage. Vishay and Maxim have precision switches which are industry standards with higher voltage ratings such as the DG201 and DG202, but do not have an oscillator built in.

Walter Heissenberger
Hancock, NH

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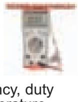

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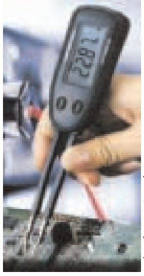

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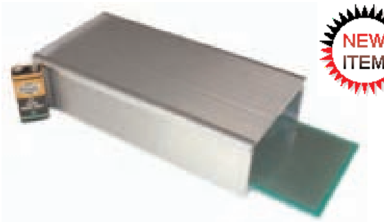

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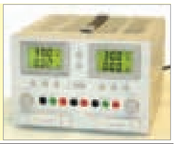

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BK4050
Hot Air with Vacuum I.C. handler & Mechanical Arm

The BlackJack SolderWerks BK4050 is designed to easily repair surface mount devices. Its digital display & tactile buttons allows easy operation & adjustments. The BK4050 includes a hot air gun and a vacuum style I.C. handler.

$119.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack

BK5000
Hot Air System w Soldering Iron & Mechanical Arm

The BK5000 from BlackJack SolderWerks provides a very convenient combination of hot air & soldering in one compact package. The hot air gun is equipped with a hot air protection system providing system cool down & overheat protection.

$119.00

Complete Technical Details at:
www.circuitspecialists.com/blackjack

BK2000
Compact Soldering Station

The BlackJack SolderWerks BK2000 is a compact unit that provides reliable soldering performance with a very low price. Similar units from other manufacturers can cost twice as much. A wide range of replacement tips are available.

$36.95

Complete Technical Details at:
www.circuitspecialists.com/blackjack

BK3000LF
Digital Display Solder Station for Lead Free Solder

The BK3000LF is a compact unit designed to be used with lead free solder that provides reliable performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

$74.95

Complete Technical Details at:
www.circuitspecialists.com/blackjack

BK2000+
Compact Digital Display Solder Station

The BK2000+ is a compact unit that provides reliable soldering performance featuring microprocessor control and digital LED temperature display. A wide range of replacement tips are available.

$56.95

Complete Technical Details at:
www.circuitspecialists.com/blackjack

Our Premium Line Up for Soldering, Repair & Rework

Rugged design at an affordable price..BlackJack SolderWerks from Circuit Specialists Inc. is the industry cost/performance leader and continues our reputation of providing high value products to our customers.

The BlackJack series features upgraded designs with exciting new features to make soldering & re-work a snap. Each case is fabricated from beautiful extruded aluminum providing an advanced high tech look not available in this price range.

Seven models have been developed. If you need to work with lead free solder, we can provide a solution. If you need to work with hot air, we can provide a solution. If you need a low cost basic function soldering station, we can provide a solution.

www.circuitspecialists.com/blackjack

W W W . P A R A L L A X . C O M

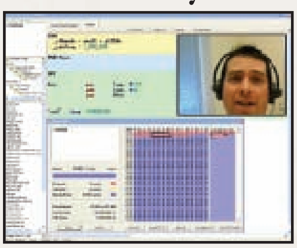
THE PARALLAX PERSPECTIVE

JUNE 2009 - BASIC STAMP, AND SX MICROCONTROLLERS, AND THE PROPELLER CHIP

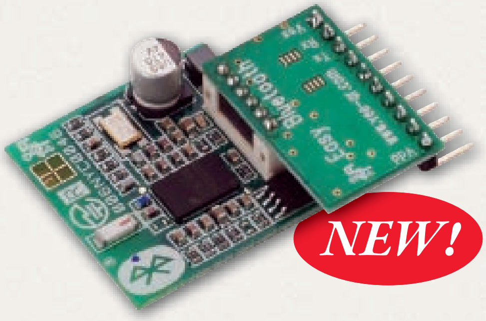
Free Educator's Courses

Parallax is offering free pilot courses at our Rocklin, CA, office for teachers interested in getting started with or furthering their BASIC Stamp knowledge and skills. Visit www.parallax.com/education for details and to request a date that fits your busy schedule. The next course is June 22-23, 2009.

More Webinars on the Way



Having run our first series of successful Propeller Webinars, Parallax is planning more. Attend Webinars from the comfort of your own computer and get your questions answered. Check www.parallax.com/go/webinars for the schedule. Space is limited to maximize attendee experience. Webinar archives are also available online.



Easy Bluetooth Module

The Easy Bluetooth Serial Module (#30085; $69.99) is an effective and low-cost solution to free your hardware applications from wires. The module is small in size, and with its SIP header design, it can fit on any 0.1" spacing breadboards for rapid prototyping. The module can be powered with various voltages since it has an on-board regulator, allowing it to be used with all Parallax microcontrollers. The RBT-001 module is removable, so various other applications can be designed without the SIP header attached if desired. 1.x & 2.0 Bluetooth Compliant.

CO Gas Sensor Module

The CO Gas Sensor Module (#27931; $29.99) is designed to allow a microcontroller to determine when a preset CO gas level has been reached or exceeded. Interfacing with the sensor module is done through a 4-pin SIP header and requires two I/O pins from the host microcontroller. The sensor module is mainly intended to provide a means of comparing carbon monoxide sources and being able to set an alarm limit when the source becomes excessive. Compatible with all Parallax microcontrollers.

Propeller Chips Now Only $7.99!

Parallax is pleased to announce that we have reduced the price on Propeller chips from $12.99 each to $7.99. Our costs on all three chips (P8X32A-D40, P8X32A-Q44, and P8X32A-M44) have reduced and we are passing the savings on to our customers! Be sure to take a look at our high-quantity pricing as well.

Attend an Unofficial Propeller Expo

Propeller Discussion Forums contributor Jeff Ledger (aka "OldBitCollector") has organized two more Unofficial Propeller Expos: UPEW at Parallax headquarters in Rocklin, CA, on June 27-28, 2009, and the UPENE in Norwalk, OH, on August 22, 2009. Get more details and sign up to attend at www.warrantyvoid.us/expo/.

Order online at www.parallax.com or call our Sales Department toll-free at 888-512-1024 (Monday - Friday, 7 a.m. - 5 p.m., PDT).

www.parallax.com